This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Letter from the secretary of the treasury transmitting report of ...

United States. Dept. of the Treasury, United States

Tec 765.7

Harvard College Library

FROM

C. W. Metcalf,
Cambridge.

LETTER

FROM THE

SECRETARY OF THE TREASURY,

REPORT OF SPECIAL COMMISSION OF EXPERTS AS TO MEANS OF IMPROVING VAULT FACILITIES OF THE TREASURY DEPARTMENT.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1894.

Tec 765.7

HARVARD COLLEGE
FEB 10 1919
LIBRARY

[illegible]

U.S. - Treasury Dept.

Treasury Department,
Document No. 1664.
Supervising Architect.

53D CONGRESS,
1st Session. | SENATE. | Ex. Doc. No. 20.

IN THE SENATE OF THE UNITED STATES.

LETTER

FROM

THE SECRETARY OF THE TREASURY,

TRANSMITTING

Report of Special Commission of Experts as to means of improving vault facilities of the Treasury Department.

SEPTEMBER 30, 1893.—Referred to the Committee on Appropriations and ordered to be printed.

TREASURY DEPARTMENT, *September 29, 1893.*

The PRESIDENT OF THE SENATE:

I have the honor to transmit herewith the report, with the accompanying papers, of the commission appointed under authority of a clause in the act approved September 30, 1890, making appropriations to supply deficiencies and for other purposes, as follows:

> To enable the Secretary of the Treasury to appoint a commission of scientific or mechanical experts to report on the best method of safe and vault construction, with a view of renewing or improving the vault facilities of the Treasury Department, three thousand dollars.

Respectfully, yours,

J. G. CARLISLE,
Secretary.

OFFICE OF TREASURY COMMISSION ON
SAFE AND VAULT CONSTRUCTION,
Ithaca, N. Y., March 15, 1892.

SIR: I am instructed by the United States Commission on Safe and Vault Construction to hand you the inclosed report, as representing the principal results of their investigation; which has been both careful and extended.

It has been their intention to embody in this report only the account of the methods and principles illustrated by the best modern constructions in this department, to give some idea of the methods of destruction and the risks met with through the efforts of criminals to obtain entrance into these receptacles for securities, and, finally, of the general principles which, in the opinion of the Commission, should guide the maker and the user in securing good results. It has not been the intention of the Commission to describe the various makes of safes and vaults in the market, except as illustrating types, and it is not within their province to enter into a discussion of the construction or of the relative merits of the accessories in safe-making. It was considered that the duty of the Commission was rather to supply a basis upon which satisfactory specifications might be framed.

Accompanying the report will be found a collection of documents supplied by builders, which will have much interest. These include, also, sample specifications illustrating actual and approved practice, and such as, in the opinion of the Commission, should be taken as representing constructions which should be excelled by the work done for the Department. Descriptions are also there given of the forms of lock and bolting systems built by the famous lock-makers of the time, and of accessory devices, as Clark's arrangement of platform at entrances to vaults, of the latter of which models are expected to be forwarded presently by the inventor, through the Commission. Full and clear accounts of experiments are also there given.

Very respectfully,

R. H. THURSTON,
Chairman.

The SECRETARY OF THE TREASURY,
Treasury Department, Washington, D. C.

OFFICE OF TREASURY COMMISSION ON
SAFE AND VAULT CONSTRUCTION,
Ithaca, N. Y., ———.

SIR: The United States Commission on Safe and Vault Contruction beg leave to present the following:

This Commission has been appointed under an act of Congress of date of approval of September 30, 1890, and known as the deficiency appropriation bill, "for the purpose of reporting the best method of safe and vault construction, with a view to renewing or improving the vault facilities of the Treasury Department," as stated in the bill and in the letter of instruction furnished by the Department. The Commissioners named in the constitution of the Commission by the Treasury Department, under this provision of Congress, are Robert H. Thurston, of Ithaca, N. Y., chairman; Theo. N. Ely, of Altoona, Pa.; Francis Pratt, of Hartford, Conn.

The first meeting of the Commission was called by the Secretary of the Treasury at the Treasury Department, Washington, on Saturday, the 11th of April, 1891, at 10 a. m., at which meeting the Commission was organized and the instructions of the act of the Secretary of the Treasury were given, verbally, by that officer. On the conclusion of that session, the Commission met from time to time, as its members found it practicable to appoint a date suitable to all, and in various localities as seemed best, in the endeavor to ascertain what are the usual and standard methods of safe and vault construction adopted by the best and most important banks and safe-deposit companies of the country, and to learn what are the latest and most promising of modern inventions possessing claims at once to novelty and security. In this work the Commission has visited New York City on several occasions, and has visited also Washington, Pittsburg, Rochester, Providence, and

Stamford, and has seen the best illustrations of the work of well-known builders to be found in the larger cities.

The first duty of the Commission was the careful examination of the safes and vaults in which are kept the securities of the United States Government, at the Treasury in Washington, and at the sub-treasury in New York. This was done by this body at its first meetings in Washington and in New York, about the middle and at the end of April, last.

This task accomplished the next step taken was the inspection of the safes and vaults of the great banking and safe-deposit companies in New York and elsewhere, with a view to comparing their construction and their security with those of the Government. It was assumed—and the assumption proved later a correct one—that the best and most secure depositories of the country, and of the world, would be found among these companies, and that they would give opportunity to compare the constructions of the Government with those which are thought by the most intelligent and well-informed among financiers and bankers the most perfect of available methods of protection of funds and the most reliable of constructions yet produced by the hand of man.

The details of construction were then looked into, the Commission visiting for this purpose the builders of safes and of bank vaults and investigating the methods of design and of assemblage of the structures of which they had previously only seen the exterior and interior faces. The later forms of lock and accessories were also studied, the makers being visited for the purpose of ascertaining precisely how they were constructed and the quality of their workmanship. A variety of forms, illustrating the remarkable ingenuity of the inventors of modern bank locks, and the no less admirable excellence of their construction, were thus examined, including the most recent of these wonderful constructions: the automatic systems of adjustment of the time lock to the bolt system, so as to secure an automatic opening of the bolting by the action of the time lock at any desired and stated hour.

Finally, some of the more radical and most important departures from the usual and standard systems of construction of safes and bank vaults, embodying the application of new and hitherto unused material in this department of manufacture, were very carefully studied, tested, and very fully considered.

During the course of the work of the Commission, also, the reports of the expert employed at an earlier date by the Department were placed in the hands of the Commission, and their statements and conclusions carefully debated and compared with what the Commission had itself had been able to learn. The opinions of such officers of the Department and of financiers, bankers, and others competent to pronounce upon this subject, as well as of the various builders of such work, were freely received and given due weight; the result being that, through direct experiment and the testimony of sometimes competing and rival makers, it was finally considered that the field had been very completely explored and reliable conclusions seemed attainable. These conclusions are the subject of this report, and they will be presented with some account of the work of the Commission in detail, and of the facts and deductions from experiments made by or for this body as furnishing their basis.

The Government vaults at Washington and at New York, in the Treasury and in the subtreasury, contained at the time of our examination about $700,000,000 in bonds, notes, and coin. Of this, about $90,000,000 in silver coin was hoarded in vault No. 1, about $80,000,000 in gold in No. 2,

$8,500,000 in negotiable notes in Nos. 3, 4, 5, and 6, about $220,000,000 in national bank securities in No. 7, and nearly $300,000,000 of reserves for replacement of worn and mutilated notes were stored in No. 8. These 4,500 tons of coin and $550,000,000 in bonds and notes are all preserved in vaults of varying degrees of security; but no one of the eight vaults in the Treasury at Washington represents either modern or approved construction, such as would be considered by a banker in a country town, East or West, desirable on the score of both pride and ordinary business discretion. They are neither a source of satisfaction to the officers of the Department as representatives of the best or even of good modern construction, nor are they illustrative of that fine workmanship and finish which has come of late to be considered as only second in desirability and suitability in every important bank to safety. As they stand they are not simply lacking in the elements of excellence distinguishing the latest constructions of this kind; they are absolutely discreditable to the nation and to its mechanics and to the Department to which the care of the stored wealth of the Government is confided.

Taking the several vaults in order: No. 1 is a large vault in the basement, 50 by 90 feet on the floor and 11 feet high, and not constructed as burglar-proof in the usual sense of that term. Its inaccessibility from the outside, and the fact that it is only used for silver, the removal of which in any large quantity would be impracticable by burglars, even if it were reached at all, as well as the efficiency of the guards, are relied upon for security. No. 2 is a masonry vault, steel-lined, and, like No. 1, has good doors and locks. It is for its time a very good piece of work. Nos. 3, 4, and 5 are totally unfit for the purpose intended, while Nos. 6, 7, and 8 similarly exemplify the antiquated character of many of the constructions in which the Government securities are kept. No one of them would be regarded by the average Government or bank officer as either representative of good modern practice or creditable to the most modest country bank in the United States. It may be readily understood why this Commission considers them altogether discreditable to the Department and the nation. The Treasury Department of the United States should possess the most absolutely secure and most perfectly constructed system of safes and vaults that the art of man can to-day produce.

Safes are in use only in the Redemption Bureau, where we find several employed for the storage of bills in comparatively small quantities at night. These safes are now a quarter of a century old, and it is needless to say are not suitable to their place or their purpose. If safes are to be used at all in the Treasury they should be the best that can be found, and should be replaced by later and better constructions, as the progress made by the builders permits a gain in security to be thus attained.

The real safety of the Treasury lies in its system of guards and police protection, a somewhat costly but a very effective system, where, as here, the number employed may be made so considerable that their sudden attack and capture or their bribery is rendered improbable or perhaps quite impracticable. Any system which keeps the deposits under the eye of any considerable number of persons is the safest possible against all but mob violence.

The Commission found that the storage capacity was already too small for the regular purposes of the Treasury, and considered that the continual increase of storage demand would make it advisable to very soon greatly enlarge in all divisions. Your Commission are in this matter, therefore, in accord with the officers in recommending a complete and absolutely satisfactory reconstruction so far as practicable, the building of additional vaults, and the introduction of a sufficient number of modern safes—if they are preferred to a vault—in the Redemption Bureau to accommodate the Department fully for many years to come.

The nature and probable cost of these extensions had already been substantially determined by the Department before the appointment of this Commission. Their extent, as then proposed, may probably be taken as a minimum requirement, and the cost of the construction, whatever the form ultimately settled upon, may be safely taken, it is judged, at approximately in accordance with the estimates then made by the Treasury; which estimates were apparently very liberal for the moderate extensions then suggested. This Commission would be inclined to consider the entire replacement of the present vaults and safes by the latest and best constructions a very wise and, as a matter of insurance, economical measure.

While this work is going on this Commission ventures to suggest that the opportunity should be taken to make all the offices, and especially in the Redemption Bureau, where notes are handled in such large quantities, absolutely safe against assault by organized gangs and against sneak-thieves, by the adoption of all those simple but universally employed expedients which are to be seen in every banking office of any magnitude in the country. While the policing and the guards of the Treasury make it safer than are the majority of banks against this sort of attack, it is unwise and inexcusable to neglect these minor and inexpensive precautions.

The subtreasury at New York was found by the Commission to be more satisfactorily protected than is the Treasury at Washington. In some respects, however, improvements may be effected, and the Commission would respectfully suggest that the officers of that, and of other subtreasuries as well, be called upon to give a minute report of the condition of their vaults and on desirable improvements, securing one or more expert advisers in making up the details of proposed constructions, extensions, and alterations. It is especially important, in the view of this Commission, that the enormous deposits of Government and other securities held in the vaults of the subtreasuries in the large cities, and at the mints, also, be made as safe as art of man will permit, against both internal and external enemies and against both burglars and mobs. While the deposits of the Government at Washington and elsewhere are as safe as the circumstances permit them to be made, in the absence of the latest improvements of construction and invention, and may be termed, all things considered, reasonably safe, it is not the fact that they are protected as effectively, their guards apart, as are private deposits of vastly less magnitude and importance, or nearly as effectively as modern methods of construction and modern inventions make readily practicable.

In the following report it is proposed to describe, first, the method of building safes and bank vaults of the usual and standard forms by the best makers, the characteristics of the materials of which they are composed and the method of their utilization, the system of securing their doors by locks and accessories, and the later forms of automatic operation of the bolting and locking devices. It will then be attempted to indicate what are the more striking of newer inventions and forms of safe and vault, not yet generally and widely introduced, or considered as yet standard, and to give some idea of their relative claims and values so far as our, as yet, limited acquaintance with them may permit. Some experimental work exhibited to the Commission, or performed under their supervision, will be described in this connection, and the less important aspect of the liability of safes and vaults to attack as by mobs, may be briefly referred to. Finally, some interesting methods of reënforcing the usual methods of protection by accessory systems may be discussed, and their promise, as judged by their information and experience so far available, may be in some degree indicated.

The recommendations of the Commission, as to extent of additions and alterations of existing constructions under the charge of the Treasury Department, will be based largely upon the requirements of the Treasury as defined by its own officers. Their form as respects character of construction will be based upon the general experience of bank officers, the results of experience during years past with the standard forms of safe and vault, as attacked by all the innumerable devices that the burglar, the boldest and most skillful and ingenious of all mechanics, has been able to bring to bear against them, and upon the knowledge and testimony of experts and of the members of the Commission, as modified or reënforced by their own direct experiments. It will be assumed that the Government should have the reputation, as well as enjoy the certainty, of having the most absolutely safe system of preservation and protection of its enormous wealth, in the form of deposits in its Treasury and subtreasuries, and its mints, that the art of the modern mechanic and inventor has been capable of devising and providing; that its safes and vaults should illustrate the best workmanship that the American mechanic can produce; and that its officers should be given every facility and convenience that experience has shown to be desirable and practicable in the handling and protection of securities intrusted to their care.

Standard modern safe and vault construction, as it has taken shape during the generation just ending, has come to one practically universal general system. All the best-known makers and every manufacturer doing any large business adopts the same plan, in the main, and the differences observed among them are in details of construction and assemblage of parts. The chamber designed to be burglar-proof is, in such construction, made invariably of alternate layers of soft and tough steel or iron of similar quality as nearly as may be, and of plates of steel hardened as intensely as is found practicable; the two metals being laid alternately, one over the other, in the walls of the chamber, in such manner as to finally constitute as nearly as possible a single mass. The idea of the constructors is to insure strength and toughness and permanence of form by the use of the softer but more ductile material, while the harder (but necessarily comparatively brittle) metal gives a certain immunity from the dangers of attack by drilling the mass.

The softer metal is, in the best work, the best and toughest of the so-called "mild" steels made by the "open-hearth" or the Bessemer process, a metal which possesses all of the finer qualities of the best and toughest and most ductile irons, together with that freedom from lamination and "cinder-streaks," or other defects of structure, which can never be attained with iron, but may always be observed in the best steels. The harder metal is either "high" carbon steel, of the tool-steel quality and characteristics, or is one of the singular iron compounds known as the "self-hardening" steels, as some of the alloys are termed. It is usually a hard chrome steel, the alloy of iron and chromium, the latter in very small doses, being found to weld readily and comparatively thoroughly with adjacent layers of iron. A common method of manufacture is to alternate three layers of iron or soft steel with two intermediate layers of steel capable of taking on extreme hardness, and to roll them down together, hot, to form one sheet of about one-half inch thickness, finally tempering it in such manner that the imbedded steel plates will offer very great resistance to the best-tempered drill or cutting tool, or perhaps even completely resist its entrance beyond the outer iron layer.

Composite sheets of this sort are then built into the walls of the safe or vault, alternating with heavy half-inch iron or soft steel plates; and a thickness of several inches is thus obtained, capable of at least retarding the operations of the burglar sufficiently to prevent his successful penetration of the interior within the period ordinarily available for his work. Absolute impenetrability is unobtainable and is not expected; but if the walls can be made so thick and of such resistant material that it may reasonably be expected that the attack can not be made successful within the time available during the night or through the interval of a Sunday or other holiday, or possibly two coming together, it is considered that the result is quite as satisfactory. This, then, is the aim of the builder; while the object of the criminal attempting entrance is to secure such tools, and to adopt such expedients, as may give him reasonable expectation of reaching his object and getting away with his plunder in the few hours thus usually at his disposition.

The inventive powers and the constructive skill of the builder and of the burglar are thus continually pitted against each other, like the makers of modern guns and armor, and with the inevitable result of steady improvement of the construction and constantly closer approximation to impenetrability, both absolutely and relatively. Some of the most interesting and instructive and, in some directions, most valuable inventions and improvements in construction, have resulted from such contests in this field, and the modern safe illustrates wonderfully admirable applications of talent.

As a general rule, the most vulnerable part of the structure is the door and its fastenings and the adjacent parts of the walls. The door is commonly made thicker, often much thicker than the walls of the chamber elsewhere, and it is reënforced, and its locking and bolting systems are made effective for their purpose by the most ingenious devices to be found in the whole range of mechanics. It is here, in fact, that the ingenuity of the modern mechanic is mainly demanded and principally displayed.

The door of the safe or vault is constructed, like the walls of the chamber itself, of alternate layers of soft and ductile, and hard and brittle, steel. The only opening through it is for a small steel spindle, also made of combined hard and soft material, often twisted together and welded into a single piece; and even this small hole, plugged as it is by a piece extremely difficult to attack or remove, is now often omitted, and the purpose of the spindle, that of moving the bolts when released by the lock, is accomplished by an "automatic" system of mechanism, set in operation at the desired hour by means of a "time lock", having a clock movement capable of determining the precise moment at which this action shall take place, and as previously arranged by the officer in charge of the safe.

The most vulnerable portion of the construction then becomes the edge of the door, where more or less difficulty must always be found in securing an absolutely tight joint, impervious to the liquid explosives now familiar to safe-maker and burglar alike. A nicely machined and fitted edge and jamb, and sometimes a packing introduced between the two, are the final resources here; but this remains, in all forms yet devised, a somewhat dangerous line of weakness, as compared with the remainder of the structure. In a few cases, and in small safes, this fitting of the door is effected by giving it a circular form, and turning it and its frame nicely in a lathe, thus securing a more perfect joint than is probably practicable by any other method. Whether this method, even, gives complete immunity from this most dangerous method of attack seems still somewhat uncertain; but it is the best that can be done to-day. It is not usually considered applicable to large safes, or to vaults; although this commission see no reason why it should not often find application in such cases.

The bolting and locking system in use, generally, in the modern safe or vault, consists of a series of steel bolts of great strength, secured upon the inside of the door, and actuated by a small spindle passing through it, or by an automatic mechanism. This system of bolts, when thrown into place, fastening the door, by their engagement with the sockets made for them in the jamb of the door, on all four sides, is locked by a steel block, held in place by the locks, and in such manner that it may easily and safely sustain all the pressure that can be possibly thrown upon it, in the effort to throw the bolts illegitimately, without bringing any load upon the parts of the lock.

The lock proper is thus actuated either by a "time" system, a clock mechanism, set to automatically act at the appointed time, or by a spindle forming part of a "combination" capable of an immense number of different variations; which combination must be correctly set before it is possible to throw the bolts. Where this method is employed, the lock spindle, a small rod of steel and iron, or other satisfactory material, is passed through the door beside the bolt spindles. This compels the piercing of the door by two spindles; the time lock requires but one; and the automatic system has none.

A bank vault of the usual type thus consists of laminated walls of alternate hard and soft steel, entered through a door of similar construction, locked by a set of heavy bolts which are, in turn, fixed, when thrown, by the action of a lock, either "combination" or "time," and sometimes by an "automatic" system which also unlocks the door at a stated time, fixed in advance by the officer in charge.

Variations are introduced into this standard general construction by the various makers; each having, usually, some peculiar and generally patented device which gives that maker control of a characteristic form of safe or vault, which may be called by his name, and thus a place in the market secured. In many cases, these devices are of real importance; in others, they are merely patentable minor details of no other importance than as aiding in holding a specific construction for business purposes.

Thus, one maker, the Herring Company, introduces, when desired, a layer of "franklinite" in place of the steel employed by the average maker, with, as is claimed, the result of securing greatly increased resistance. This substance is a fine grade of cast iron, containing a considerable percentage of manganese, the presence of which gives it extraordinary hardness, greater, as is claimed, than that of any hardened steel. The material is, however, very brittle and crystalline, and is easily fractured by a sharp blow. To meet this objection, it is cast upon a network of iron or steel rods; so that, though fractured, the parts may still be held together by the tougher metal. Thus arranged, the inch or inch and a half of franklinite plate is found to give a real accession of resistance. It is usually substituted for a half-inch iron-and-steel plate.

Another maker employs a peculiar form of bolt, for connecting sheet with sheet, in the assemblage of the parts of the side walls. This system of bolt connection as ordinarily made consists of a set of "tap bolts," each penetrating the sheet which it is to hold and screwed into the next outer sheet, thus holding the one to the other. Another set connect the second of these to a third and next outer sheet, the two sets of bolts "breaking joints" in such manner that no hole penetrates more than two sheets. All the sheets composing the wall of the vault are thus connected, the whole being built up from the inside outward.

No bolts are seen on the exterior, in some makes, the outer sheets being only drilled partly through, and the tap bolts uniting them to the next inner sheet being tapped only part way through the outside plate, which should be made heavier for that purpose. In the case of the make here especially referred to, the builder makes a cone-shaped bolt, threaded all the way from end to end, and without head, which bolt can be screwed into the two sheets to be united by it; thus constructed, it gives no hold for the clamps or nippers sometimes used in attacks on such structures, for the purpose of drawing out the ordinary bolts. These bolts are made of welded bundles or fagots of steel and iron rods drawn down to size, and then *twisted* to make their destruction by drilling impracticable.

The same makers, the Hall Safe Company, modifies the construction of the door, with a view to securing immunity from the danger of their being forced by the use of wedges inserted between the door and its jamb. The edges of the door are made with a set of dovetails, engaging suitably with the corresponding parts of the jamb, thus obtaining a system of interlocking which, with good fitting, makes the two substantially continuous and prevents the opening of the crack between them by the springing of the door under the pressure of the wedge.

The door-spindles, giving, as they do, a possible opening into the safe, once they are removed and the hole through which they were passed is exposed, are evidently points of weakness in such constructions. This difficulty is met, in some cases, by dividing the spindle into two parts, each passing half through the door, but at different points, and the two connected in the middle of the thickness of the door by a system of small gears set into recesses suitably made in the mass. No continuous straight hole being in this case employed, it is considered that greater security is obtained. In another construction the spindles consist of a series of small cylinders and larger discs set along a common axis with the expectation that the removal of such a piece made, as it is, of steel and iron, or of hard and soft steel, will be found a matter of much greater difficulty than in the case of an ordinary straight spindle. One maker uses a spindle of large size and heavy construction, assuming that the difficulty of entrance by this point is increased with increase of size; while another makes his spindles as *small* as is possible, retaining sufficient strength to throw a system of easily moved bolts, believing that the smaller the hole through the door the less the danger of serving a useful purpose, from the burglar's point of view.

Locks are employed in great variety; but they are usually, now, of either of the three classes which have been already referred to: "dial" or "combination" locks, simply; "time-locks" simply; "automatic" time-locks; or they are combinations of the first two. There are many forms of each of these locks; but their general construction, and the principles upon which they are fundamentally based, are substantially the same, and are so familiar to all who have to do with this kind of mechanism that detailed description is here unnecessary. The value of dial-locks depends somewhat upon the number of possible combinations, as well as upon the excellence of its general design and construction. They are therefore made with such a number of possible combinations that the finding of the combination in use, by trial, is made entirely out of the question; it involves the selection of a single arrangement out of millions. The solidity and fine finish of the lock insures permanence of satisfactory working, and certainty of being able to resist any force likely to be brought to bear upon it.

The time-lock includes the delicate mechanism of a good timepiece; and this means possibility of failure through breaking of springs, or other accident, either in its ordinary use or when jarred by the blow of the burglar on the outside, or by the action of his explosives. As an insurance against such failure of the lock and against the resulting "lockout"—one of the most serious accidents occurring in the use of safes and bank vaults—two, three, and sometimes even four clock-movements are introduced, either of which will do the work required of it, and thus, in the event of any one of the movements failing, the others may act. They are subject to regular inspection and the chances of any one failing are very slight; the chances of two failing at the same time are unimaginably small, except where seriously shaken by the action of high explosives, in which contingency there is less objection to its occurrence. With three or four time movements, there is practically no possibility of failure to act at the intended time. To evade even the possibility of injury by explosives acting on the exterior, these clock-movements are sometimes mounted upon springs. The most recent constructions of the time-lock are thus safe against all known contingencies of practical operation, embodying, as they do, the most excellent workmanship, the fruits of the highest ingenuity, and the most perfect adaptation of mechanism to its specified purpose seen in modern mechanism.

The automatic system, like the simple time-lock, in its novel features, involves additional risk of breaking springs. It is therefore made with duplicated and triplicated sets of springs, and thus given security of equally high order with the time-lock—probably, if possible, still higher. In this arrangement, when the time for throwing back the bolts of the safe-door arrives, the time-lock releases a trigger, which sets in action a set of heavy springs; these springs, in turn overcome those which, on closing the door, throw the bolts into place without aid from outside, and thus the bolts are withdrawn at the intended hour and the door may then be opened. A large surplus of power in the locking system of springs, and a still more liberal excess of strength in the unlocking system, with duplication of parts, gives all desirable security against failure to act. Assuming this security ample, in any given case, the fact that there is no opening through the door, no spindle, for any purpose, gives great certainty of protection, and makes this, the latest device of its class, the most secure.

One of the principal, if not really the most important, reasons for the now universal adoption of time-lock systems, automatic or other, is that, with a combination lock, without reënforcement by the time-lock, it has been not infrequently found possible for the burglar to find the holder of the combination, to compel him, at the point of the pistol, to go to the bank and to open the safe. On several occasions the officer thus captured has lost his life, refusing to aid the criminal who, disappointed, has thus revenged himself. With the time-lock, in either of its forms, it is out of the power of the officer seized to open the door, even if he should be willing to do so, and the burglar, recognizing this fact, does not add to his own risks by calling upon a bank officer when he is aware that the time-lock is in use. He is usually well-informed as to the character of the problems confronting him before undertaking to solve them, having always, if an expert, taken ample time to inform himself, and often studying the construction of safe, vault, building, and surroundings, and the habits of the officers and guardians of the establishment, for weeks or even months beforehand.

The methods of attack adopted by burglars in the endeavor to plunder a safe or bank vault are perfectly familiar to two classes of persons, —the burglars themselves, and expert safe-makers—and are also often well-known to bank officers. There is therefore, in what is about to be stated, nothing new to these classes, and there is no objection to publication in the endeavor to make clear what this Commission has sought to accomplish and what has been ascertained.

There are four principal, usual, methods of obtaining entrance into safes and bank vaults by professional burglars; all involving the necessity of finding a time when the bank or vault is left unguarded, or so insufficiently guarded that the burglars may readily secure undisturbed possession for some hours. Such opportunities as offer when a holiday gives an extra twenty-four or forty-eight hours for work are most desired; but a single night is the most usual period of their operations. In rare instances, time is taken for making approaches by concealed paths, as by tunneling from an adjacent building, and days or even weeks may be occupied in preliminary reconnoissance, and it often happens that weeks are given to learning the exact construction of building and vaults, the habits of the cashier and other officers and attendants, and sometimes to the making of the acquaintance of and to effectively bribing the watchmen. It is generally considered, however, that the time that may be occupied must be confined to the few hours between the time of late closing and early opening of the bank and adjacent shops and offices.

The four methods are:

(1) Drilling or otherwise penetrating the walls of the safe or vault or its door, and thus obtaining access to the locks and bolts, and then, very generally, opening them from the inside.

(2) Stripping the wall of its covering, layer by layer, tearing off the steel and the iron sheets, one by one, until the interior is reached.

(3) Exploding gunpowder, dynamite, or nitroglycerine in some part especially easy of attack by this means, and thus destroying the locks, tearing open a door, or actually breaking into the walls of the structure. Powder is sometimes blown into the crack left by imperfect construction about the door and between it and its frame or jamb. Nitroglycerine is often run in the same crack where not absolutely tight, and, flowing as freely when warm as water, it finds its way in considerable quantities and along a considerable extent of edge, and, when fired, either rips off the door, tears off its outer layers, or at least makes an enlarged space into which a larger charge may be more effectively introduced. The minute space between the lock spindle and the surrounding metal is similarly found to be a weak point in usual constructions. Dynamite is sometimes, where the conditions are especially favorable to the use of large charges of powerful explosives, forced into cracks or laid against a weak spot, and well tamped by any convenient means; being fired, it may either make an opening or may produce a weakening effect, of which advantage may be taken in subsequently operating with tools or with other explosive charges. It

is barely possible that occasions may arise, a mob, including men of sufficient skill and experience, making an attack, and when such explosives may be obtained in quantity, when heavy charges may be fired regardless of the sound and jar of the concussion; in such cases, this latter method may prove the most dangerous of all. Such cases, as a matter of course, must be rare, and, in the case of Government depositories, where an ample guard, well-armed, is sustained, is not to be considered as one of those to be apprehended.

(4) Where combination locks only are used it has occurred that the burglars have sought the cashier or the officer entrusted with the combination, and have forced him to go with them to the bank and there to unlock the doors, giving them immediate access to the interior. Time locks—the automatic system or other—and a divided or a multiple combination are the expedients which meet this form of attack.

Of these several methods of securing entrance into the safe or vault the first, because of its comparative freedom from noise or jar, is the favorite, where practicable and when time is given for its slow but usually certain operation. Although it is the fact that the safe-builder aims at securing, in the steel sheets introduced into the composite walls of the structure, such hardness that penetration by any steel tool is not to be apprehended, the fact is that both the quality and the temper of the steel tool may, by careful selection and skillful hardening and tempering, be made superior to the average sheet steel thus employed in construction; and by the use of a number of such carefully made and tempered drills penetration, slow and toilsome, but, if not interrupted, ultimately sure, may be anticipated. In some cases the use of a compound blowpipe, employed to heat the spot to be attacked, and thus to draw the temper of the steel to be drilled, is practicable, and the task, in such cases, is rendered comparatively rapid and easy. This is not, however, usually practicable, except where a large hole is bored, and the access of the flame to a large surface is thus made possible.

The high conductivity of iron and the close contact of cold adjacent sheets makes heating by a small flame, and through a small hole in the covering sheets of soft metal, very difficult. Holes of an inch diameter are as large as are commonly attempted; but it is not especially difficult to bore holes 2 inches or more in diameter, and thus not only to gain opportunity to use a large flame but also to break up by hammering any internal armor too hard to attack otherwise and of which the temper may be difficult to reduce by heat. This process is, in fact, sometimes adopted where the blowpipe is not used, the soft sheets being bored and the intermediate hard sheets broken by the blows of a hammer and removed piecemeal. Where the best tools and the most favorable conditions conspire to favor the criminal it may be reckoned that he will enter at the rate of about an inch an hour. If his steel is not of the best quality, if his skill in tempering is not exceptional, and if the sheets are of the best make, he may break or dull the edges of all his tools and find himself able to penetrate only the outer sheet of soft iron or steel, and finally compelled to give up the attempt, his whole stock of tools exhausted.

Stripping the safe of its outer covering is sometimes effected, the use of hammer and chisel being considered safe, the sound and jar of the repeated blows not being likely to be perceived, as where an isolated building is attacked in a stormy night, the inhabitants and the guards being either absent or captured and safely bestowed. With room to swing a sledge, and provided with plenty of chisels and good wedges, the burglar sometimes finds this task a comparatively simple one, though laborious and slow. Once the outer casing is cut through, along any convenient line of separation, the wedging off of sheet after sheet is found a better method of attack than drilling. A single uninterrupted night's work sometimes gives entrance into the heaviest of safes. Your Commission have seen a large and well-built safe thus practically destroyed by four hours' steady work, using no other tools than a heavy sledge, cold chisels, and the wedge. In this process the sheets of hardened steel, or other drill-proof metal, offer comparatively slight resistance, and are easier removed than the plates of softer metal. The essentials to success are mainly ample room to swing a heavy sledge, or to handle a hammer and cold chisel, plenty of time, and reasonable certainty that the sound or jar of heavy blows may not attract attention.

When the attack is made by a well-organized and well-equipped party of "professionals," provided with a good "kit" of the best tools, with a stock of high explosives, and having taken such precaution as to be safe against interruption during a night's work, the use of one or of a combination of these various methods becomes fairly certain of result. Drilling is always safe, under such circumstances. The high explosives are remarkably local in effect and produce singularly little sound or jar; and the sound and jar of hammer or sledge are not very likely to attract attention when the building is isolated, and especially if the night be dark and tempestuous. Where the explosive can be introduced in ever so small an amount the way is soon opened for a larger charge, if not for the use of the wedge and of the "jimmy." If the joints are too tight to admit even nitroglycerine the use of the chisel and wedge or of a drill may give access to a spot into which the explosive may be successfully introduced. Once either wedge or dynamite or other explosives finds entrance the work is certain of completion, time being permitted for their further use. The impunity with which explosives are used on such occasions is one of the most remarkable elements of this always remarkable business.

It is, all things considered, obvious that the one great desideratum in the protection of these structures against successful attack is a reliable system of watching and guarding. No successful attack can be made where the spot is visited frequently, and it is only necessary to make certain that the safe or vault is strong enough to resist safely for the full time between visits of its guardians, and that the watchmen or guard make those visits regularly, with no risk of interruption in either going to *or leaving* the spot at the assigned times, to make the deposits absolutely safe. A captured guard, however, when the immediate detection of the fact of capture is not assured, gives the attacking force the best possible assurance of uninterrupted work. A guard sufficiently numerous, or sufficiently well assured of prompt reënforcement, in case of attack or capture, to make its utility certain, is a positive insurance with any good system of safe or vault construction. With certainty of alarm in case of capture one man on guard is as good as an army; but where the deposits are of exceptional importance watchmen should always go in pairs at least. The automatic systems of alarm in case of attack, "burglar alarms" such as are presently to be described, are, perhaps, on the whole, the most satisfactory, both as alarming the burglars and as calls for a guard.

Comparing the constructions in general use it is seen that the requisites for safety are mainly two, security against penetration of walls or door and such tightness of the joints (unavoidably left) in and around the door as will prevent the introduction of explosives, either immediately or after preliminary enlargement by drill or wedge. This means the best of known materials for the purpose and the best possible workmanship, both of which requisites are often absent in the safes found in the market.

The materials used in the standard constructions, as supplied by the best makers, are usually good wrought iron, or the best of soft steel of quality similar, as nearly as possible, to that of good wrought iron; a good hardening grade of carbon steel or of chrome steel of similar grade; and sometimes special compositions, as, for example, that known as "franklinite." The latter, as before said, is a cast iron with some 10 per cent of manganese alloyed with it, and is derived from the so-called "franklinite" ore, of which large deposits exist in the State of New Jersey. Of these metals the first is employed on account of its toughness and ductility, which quality makes it an admirable material of which to make the outer casing and the sheets which are employed to inclose the hard-steel plates introduced, because of their precisely opposite quality, their hardness, and drill-resisting power.

The combination of tough and ductile with the hard and resistant metal gives that which is regarded by the builders as the most perfect possible combination for the prescribed purpose. The best arrangement is that already referred to in which alternate sheets, usually three of soft metal inclosing two of hard steel, are laid together in the rolling mill and rolled down into a single comparatively thin sheet, the surfaces, at the high temperature employed, being welded together and one of a half-inch thickness being thus obtained, which presents very great resistance to any method of attack. Chrome steel, frequently employed in this combination, is a carbon steel of tool quality, into which is incorporated a small percentage of chromium, which alloy has the double advantage of adding to its hardening quality and increasing its welding power; the latter being probably the more important advantage. The incorporation of the hard with the soft steel into one sheet by this process of welding together and rolling down gives the further advantage that the hardening of the hard steel has less effect in distorting the sheets and in introducing difficulties in the work of fitting them in place and securing exactness of bolting and close joints between plate and plate. The hardened steel is probably never as hard, in this case, however, as where the high-carbon metal is hardened by itself and then put in place separately. Very possibly a combination of the two systems may prove the best on the whole.

Franklinite is so hard that the drill will usually not penetrate it, but it is so brittle that it is easily broken by repeated blows, when the plate can be reached to strike it, though cast upon a gird of wrought iron or a soft steel netting to secure it against general breaking up when thus cracked. Its brittleness is such that it is necessary also to cast it in somewhat thick and heavy sheets in any case, and a plate thus made may fairly be taken, perhaps, as a substitute for the half-inch plate of hard steel used otherwise. It is sometimes considered wise to employ this as a superadded defense, building the wall as usual and incorparating this within it.

Writing of the quality of steel supplied safe-makers a well-known steel manufacturer says, "as a rule the steel employed for such work is the cheapest quality that is made," which would suggest the advisability, in case work is done on contract for the Treasury, of introducing into the specification a very exact prescription of quality and of tests of the steel used. The same writer goes on to say, however, "we do not think that the quality of the steel has very much to do with the built-up or laminated safes, inasmuch, as a rule, when effort is made to destroy the work, it is done by tearing the plates apart, one leaf after another, and not by drilling." This Commission would none the less advise exceedingly stringent specifications of quality of steel as well as of workmanship, and would also advise the reference of any proposed specifications to an authority having no interest in the work, direct or indirect.

Precise information in regard to the chrome and the "self-hardening steels" of the tungsten type is difficult to find. It is known, however, that they possess properties peculiar to themselves, which often make them valuable for specific purposes. The chrome steel used in safe making is stated by the makers to be tool proof, uniform in quality, and capable of welding either to iron or to itself without deterioration or loss of hardening power. A very large proportion of the steel used in this line of manufacture is said by this firm to be either made by them or to be sold as such. The samples furnished the chairman of the Commission are precisely what is claimed for them, and illustrate beautifully their excellent welding and hardening properties. The hard and soft metals are rolled into sheets and welded in the process, drawing down, at the same time, to the desired final thickness. It is supplied to the buyer soft, and is by him fitted into the structure and then taken out, hardened, and returned permanently to its place. This steel is said to harden at a low heat and to require somewhat peculiar handling for best results; but it has now been in use many years, and there is no mystery about its method of working to those accustomed to its employment. Complete analyses of this steel will be found in the report of the United States board appointed to test iron, steel, and other metals, edited by the chairman of this Commission, as also of the standard carbon steels, and a full account of their properties as developed by the investigation of that board. (This report is now difficult to secure; but the more important of its conclusions and data may be be found in Thurston's Materials of Engineering, Vols. II. and III. New York, J. Wiley & Sons, 1884–'85.) The earlier analyses of the chrome steels, as published elsewhere, are unreliable, the methods of determination of chromium in the presence of iron not having been satisfactory. In some instances, in fact, chrome steel was reported to be destitute of chromium. Those tested for the United States Board, as above, were probably very accurately analyzed. It would seem certain that the presence of chromium is an advantage in the present connection as giving greater certainty and perfection of welding in sheets in the process of rolling.

Exact information relating to the relative or the absolute security of the various forms of safe and bank vault in use as constructed by the best builders is difficult to obtain in reliable form; but this is not the place to go into great detail in this matter, and it will be sufficient to say that, in the judgment of this Commission, no one of the constructions now in the market and recognized now as standard can be asserted to be absolutely burglar proof. Given ample time and any one of them can be penetrated by the drill, blown open with high explosives or torn to pieces by stripping off, by peeling their laminated sides, plate by plate, until the interior is reached. Assuming a few hours only available, any one of them can probably, if really well-made, so that they would be passed by a skilled and conscientious inspector, be expected to prove reliable against such an attack as might fairly be expected to be made upon it. Their differences are quite as much in workmanship as in design; and only a skilled inspector can, in any given case, say whether the workmanship in any safe or vault built under his eye is what it should be. Your Commission have seen very bad workmanship in a large proportion of the safes examined. This statement is less applicable to the locks and the bolting systems, which usually illustrate wonderful ingenuity, admirable workmanship, and the best of materials. The principal defects observed in construction are bad fitting of doors to their jambs or frames and very bad fitting of plates to each other in building up the walls, as well as of the bolts intended to bring plate firmly and smoothly against plate, and to close up the intermediate spaces in such manner that neither tool nor explosive can be effectively used to separate them. These defects are often hidden by putty and paint.

Hardened plates will warp more or less in the process of tempering, and good fits and tight joints become, for this reason, matters of extreme difficulty, even in the best establishments and with the most perfect tools and the best of workmen to handle them. These facts will be accepted as ample justification of the recommendation of the Commission that any work done for the Treasury Department should be made to crarefully framed specifications and built under supervision of an expert inspector representing the Government. It should be subject to the most rigorous demands in respect to the character of materials and workmanship. It is very possible that, in some cases, proposing builders may be destitute of the needed facilities for doing such work as should be demanded, and it is well, in our opinion, to provide, in the forms furnished intending bidders, a provision that a preliminary examination of their establishments shall be made by the representatives of the Deparment to ascertain whether the contract can be carried out satisfactorily in this respect, as well as in providing specified materials.

Experimental investigations of the vulnerability of such structures have been very seldom and very incompletely made—except by burglars—and this Commission have been only able to gain such knowledge through the limited experiences of safe-makers testing their own and their competitors makes for the purpose of detecting and strengthening their weak points, and through the revelations of the methods and results of burglarious attacks upon them. The general results of these investigations have been given already, and a few more facts, in greater detail, may prove interesting in conclusion of this portion of our report.

The only published account of experiments, made to determine the penetrability of safe materials, of which we are aware is that found in Appleton's Cyclopedia of Applied Mechanics, in which Mr. Buel gives the results of his attempts to drill franklinite made under the direction of Mr. Benjamin for that work. The test was made in 1879 on a sample laminated construction, consisting of 2.6 inches of steel plate, 2.1 inches of franklinite, and 0.42 inches of iron, the order stated being from outside inward. Drills and the blowpipe were used, and the endeavor was made to make a hole 1½ inches in diameter through the structure, starting on the steel plate. The force demanded to make the drill bite into the franklinite was stated at from 4,000 to 12,000 pounds, applied to the head of the drill spindle, and the 5.12 inches total thickness was finally penetrated (though not with a full-sized hole) in nine hours and seven minutes, of which time but three hours and two minutes were occupied in actually drilling, the remainder being required to change the drills and to soften the hard steel with the blowpipe.

One hundred and twenty-five drills were used in this operation. Three men gave all their strength to the work, and the hole through the franklinite was made finally only one-eighth inch in diameter. This substance could not be annealed by the blowpipe, but was penetrated partly by drilling and partly by breaking or cracking with the heat. (Appleton's Cyclopedia of Applied Mechanics, Vol. II, p. 690.) Later experiments familiar to the trade have shown that it is easier in such instances to make a larger hole than a smaller one, and your Commission have seen the best modern work of this kind thus penetrated at the rate of 1 inch an hour under exceptionally favorable circumstances, and in the stock of competing builders may be seen all constructions of familiar safes with holes bored through their sides from an inch to 4 inches or more in diameter, and sometimes riddled with such holes. It by no means follows, however, that they are especially insecure. It is oftener the fact simply that ample time and the best of facilities have permitted the comparatively easy destruction of constructions that would have effectively baffled the attempts of the most expert burglars compelled to work silently and within a limited time.

In experiments exhibited to the Commission the alternate use of the drill and the blow pipe on walls over 3 inches in thickness of alternate steel and iron, the steel of tool quality and well hardened, enabled the attacking party to penetrate at the rate of a little less than 1 inch an hour for the whole thickness, and above 1 inch an hour for the greater part; the hole thus made being large enough to pass the arm of the workman. Many such holes in a variety of constructions of safes were examined, and the proposition already here stated, that none are absolutely invulnerable, was well-established by these observations and experiments, as well as by the general testimony of the makers themselves. All the work performed in presence of the Commission in such experimentation was done under conditions, however, more favorable than could be expected to be secured usually by any burglar, but with the same tools and other appliances.

In the study, experimentally, of the effects of explosives the Commission were aided by experts in their use. As illustrating what could be done, were a mob able to obtain possession of a safe or of a bank vault for sufficient length of time, and at the same time, were it able to find and use the high explosives, the following experiment was performed: A well-made safe, with walls about 4 inches in thickness was placed where it could be safely attacked, and 12½ pounds of dynamite exploded upon it. The result was the driving of a hole completely through the wall large enough to pass the hand through, and, though ragged and irregular, amply sufficient to admit of the opening of the safe from the inside by an expert operator.

The surfaces and edges of the injured plates presented the appearance of semimolten metal, possibly the mechanical simulation of the effect of heat. This experiment is not to be taken as representative of what might be expected to be accomplished by burglars, or, even under any familiar conditions, by a mob; but it is valuable as giving some idea of the strength of these metal constructions as now made, and of the ingenuity of the modern burglar and the skill exhibited by him in the destruction of such intrinsically strong masses.

The repetition of this experiment upon the same spot resulted in the enlargement and more complete cleaning out of the opening first made, the blowing off of the whole outside sheet, and a general shaking up of the whole safe, with much internal injury that could not be fully measured. The safe was practically destroyed.

The effect of the use of high explosives upon safes attacked in a more usual and moderate manner was best illustrated by the action of nitroglycerin introduced into a minute crack around the door of a remarkably well-made safe, unfitted, however, with a now common device, an arrangement of rubber packing to meet this case. By the use of glaziers' putty the crack was sealed on the face of the door and the safe from about the middle of its height down to the bottom and for a third of the length of the crack along the bottom of the door. Nitroglycerin was poured into this crack until 3 ounces had entered and it had begun to drip from the lower side of the door. It was then fired.

The result was the complete destruction of the lower part of the door, the serious injury of the whole upper portion, and such general disruption that the entrance of the safe by the use of the jimmy was made easy. A few minutes' work by an expert user of that remarkable tool would have given access to the contents. The sound of the explosion was not very startling, the pieces were not thrown about very much, and the tumbling out of a part of the lining of the door as its lower sheets were displaced by the explosion was the most striking effect observable by the eye.

This peculiar local and comparatively quiet though powerful action, of this class of explosives constitutes their most satisfactory quality from the standpoint of the burglar, who is thoroughly familiar with it and constantly takes advantage of it. There are probably few cases in which it can not be, in skillful hands, made most effective. In the opinion of this Commission it is exceedingly difficult to make the workmanship of the door so superlatively excellent as to completely evade this danger. It is not sufficient to make a good joint. The joint so made must be held up to its place and the contact of door and jamb, or of spindle and door, must be made so secure that the wedge, or the use of such minute doses of nitroglycerin as can be made to insert themselves by capillary action, shall not be able to enlarge this always possible capillary opening in such manner that larger charges may be introduced and a gradual extension of the opening, in this way, lead to the final use of effectively disruptive charges.

The conclusion of the Commission, after witnessing what has been described, and seeing or hearing of much more to the same effect, is that the best constructions only are in any degree safe against this attack, and that even these must be further reënforced by some reliable system of watching and guarding if absolute security is to be attained.

Systems of guarding have already been referred to as desirable in all cases, and on as complete and well-organized a plan as the magnitude of the interests involved will permit. Small banks and the minor safe-deposit companies employ usually a single watchman, who is expected to visit the guarded spot at regular and specified intervals. But a single man is easily overcome when taken by surprise and under the eye of waiting enemies. His movements become readily ascertained and the opportunity is sure to offer. By making a police station or other permanently policed spot a part of his round, with orders to the watch to report at each turn, this danger is lessened, and the burglar's only chance is then usually to inform himself of the time of passing of the watch and the period of absence, going about his work the instant the guard is past and trusting to getting into a safe position before his return. Guards in pairs are vastly safer than single men; but they, also, should report regularly and frequently at some safe external point in order that their capture, should it happen, may be immediately detected and a force of sufficient magnitude at once sent to the rescue. Where the deposits are of exceptional value the force employed as guard should be correspondingly increased, and always, however large the force, connected by regular communication—permanent if possible—with an external and still stronger body, as the public or private police force or both. In the case of the great safe-deposit companies, the Treasury of the United States and its subtreasuries, this method of protection is likely, in our opinion, always to form an essential feature of the whole system.

In the larger cities, your Commission find in successful operation one of the most interesting, ingenious, and probably reliable methods of protection and guarding that can be conceived, one that seems, where it is practicable to adopt it in all its completeness, competent to make the weakest construction safer than can be the strongest and best, if unguarded. This system consists in the envelopment of the safe or vault to be protected with an outer casing completely surrounding it in some cases, in others only protecting its most exposed and vulnerable parts; in which casing are concealed a net work of wires constituting the circuit of a battery placed at some distant and easily guarded place, as at a police station, or at the central office of the system, where an ample guard is always on duty. In some cities, hundreds of these circuits are placed under the protection of such a central guard, and the guard within the office and on its outside "beats" may number scores of men.

The current of a permanent battery of low tension is, when desired, kept constantly circulating in this circuit, and affects, at the same time, a needle-indicator under the eye of the watch at the office. The safe can not be disturbed without disturbing the circuit and giving the alarm by causing the needle to drop back to zero, and usually ringing a bell as an alarm. An attempt to remove the wires is sure to result in the breaking of the current. Whether the safe is opened by friend or foe, a record is made at the central station, and this is carefully preserved as evidence, should it be called for later. Regular reports are made by the office and sent directly, at prearranged intervals, to the proprietors of the safe thus protected. In case of an irregularity, the proprietor is immediately notified and, meantime, a guard sent directly to the safe. The system is as simple as it is complete and the inventor, Mr. Holmes, has established a considerable number of stations in the city of New York, in Boston, and elsewhere, which are, so far as the observation of your Commission and general testimony indicate, most satisfactory. We are pleased to find a modification of this system in use at the subtreasury in New York, where these accessory systems of protection are more completely developed than elsewhere in the care of Government deposits, as the dangers of attack are probably greater in so large a city. The method is one capable of very extended application, and would find useful application at the Treasury, where, if applied, it should be arranged to bring into the circuit both the police station nearest the Department and the residence of one or more of the officers of the Treasury. Points difficult of protection by the usual system of armor, or which it would not be thought economical, on the whole to so protect, can be by this method made safe.

The latest forms, as yet insufficiently well-known or introduced to be considered standard constructions in safe and bank vault building, include at least one important class, and in this class at least two types that have been strongly urged upon the attention of the Department and of the Commission. It has constituted one part of the work of the Commission to endeavor to ascertain whether these may be seriously considered, in calling for plans and in asking tenders for construction of vaults for the Treasury, and if so, what degree of security they may offer, and how they may compare in this respect with the so-called standard makes which have been described in this report.

This class of constructions differs from the preceding in the method of securing the same general result—a combination of strong and tough material with a hard and presumably impenetrable stratum in a single mass—both in the character of the metal employed and the final result. Instead of a series of sheets, constituting a built up structure, this forms a single mass of the same metal, the two qualities sought being obtained by modifying the character of the metal from inside to outside in such manner as to give an immensely hard and resistant exterior integral with an interior of comparatively ductile, though soft and strong, though penetrable material.

The metal employed is a peculiar grade of iron, such as is used in car wheels and other constructions in which its singular property of hardening with "chilling," with sudden cooling, is desirable.

When this iron is melted and poured into a mold in the usual manner, it is found to be a very strong and dense and homogeneous iron, very much stronger than common cast iron; so much so as to constitute a separate class, formerly generally known as ordnance iron, from the fact that it was that of which the remarkable cast-iron ordnance of earlier times was made, by Major Wade and Admiral Dahlgren for our Army and Navy, during and before the civil war. It is to-day mainly used for the manufacture of the better grades of car wheels, giving them properties which are a constant source of astonishment to European engineers and railway men. Its strength and ductility are vastly greater, and its "resilience" or blow-resisting power is many times greater than that of common irons. (See Materials of Engineering, Vol. II, pp. 440, 441, 442, and Report on Salisbury Irons; Railroad Gazette, 1877, also separately printed.)

Common cast irons have a tenacity of about 20,000 pounds per square inch, common wrought irons about 50,000; while this metal, when of good quality, exceeds 30,000 and possesses five to ten times the ductility of the cast iron of the ordinary market. Its property of hardening by a sudden chilling is its most remarkable characteristic, however. On "pouring" this iron into a mold of which any portion is composed of a heavy mass of cold iron, the immediate reduction of the temperature of the molten mass to that of the colder iron, produces an effect similar to that observed in hardening steel; and with the result, peculiar to this case, of giving a permanent hardness which can not be removed by simply heating to a red heat and slowly cooling, as in the case of steel. It can only be altered by remelting and the hardness thus produced in good metal exceeds that of steel tools. In fact, it is not now unusual to substitute tools made of this metal for those of steel when, as sometimes in boring a steam-engine cylinder, the metal is found too hard to be readily cut by common tools. The Pennsylvania Railway Company in its shops at Altoona, has for some years past customarily employed chilled iron tools for such work as demands a hard and permanent edge while cutting at high speeds.

The best of these irons are found at localities both in the East and in the West, well-known to all car-wheel makers and chilled roll manufacturers, and they are always found in the market, where they sell at prices considerably higher than those obtained for the ordinary brands of iron for foundry purposes. Their peculiar qualities depend upon chemical properties as yet not fully ascertained; though it is known that the process of chilling involves the conversion of the graphitic carbon, existing in the iron when soft, into the combined form, thus securing a carbide of iron which is crystalline and immensely hard. The chilling quality of the iron is exhibited by the depth of the chill, which, in many cases, can be obtained to a depth of 2 inches or more from the surface in contact with the "chill," as the mass is called which produces this hardening by its contact. The specific gravity should be about 7.2, and 7.25 may even be reached to advantage. (Materials of Engineering, Vol. II, Iron and Steel, p. 440; Manual of the Steam Engine, Vol. II, pp. 479, 480; also pp. 537, 538.) Such irons have been known to attain a tenacity as great as that of the softer grades of wrought iron, unchilled, and a hardness, chilled, exceeding that of hardest tool steel.

A special advantage of this class of metals for the production of such constructions as are here under consideration, is their easy melting and casting into any desired shapes, and still more important, the readiness with which any desired construction may be thus produced with a chilled surface wherever it be required, outside or inside, and complete, or of limited extension on the outer or inner surfaces. The insertion into the sand molds, in which the piece is to be cast of a mass of cold iron, of sufficient thickness to promptly cool the molten mass as it enters upon it, insures that the portion so affected shall be made intensely hard, while the remainder of the mass may be soft, so as to be easily worked. This process is a very old and familiar one to the engineer and the mechanic working in iron, and has been used for an unknown period, as, for example, in the chilling of the faces of anvils, to render them safe against injury by the blow of the blacksmith's hammer.

When and to what extent this material has been proposed or actually used in the construction of safes and bank vaults, this Commission have no knowledge; but, so far as they are able to ascertain, no serious attempt, and no at all successful endeavor, to make the metal useful in this manner was made until recently.

Some years ago, Mr. William Corliss, of Providence, R. I., while still engaged with his brother, Mr. George H. Corliss, in the manufacture of the Corliss engine, in that city, devised forms of safe which he thought sufficiently promising of value to place on the market. He built an establishment, organized the Corliss Safe Manufacturing Company, and has since that time made this his principal business. Various changes and improvements effected since the first inception of this idea have brought this construction to a stage which makes it, in the opinion of your Commission, worthy of careful study, and it may be considered as fairly out of the stage of experiment, and as among actual marketable constructions. Mr. Corliss has also recently devised forms of vault and safe doors, for use with fireproof constructions which possess interesting novelties of detail and important advantages over older devices, and has, still later, invented a form of safe or vault especially suited for larger constructions, and intended to compete with the standard forms of bank vaults already described as in use in the larger banks, and by safe-deposit companies of the larger class. This Commission has very carefully examined these devices and the safes and vault doors made by Mr. Corliss, and also the establishment in which they are constructed, as well as the drawings and models of his latest invention, the chilled-iron vault. Descriptions of these inventions will be presently given.

The second of the chilled-iron constructions above referred to is that built at Pittsburg and elsewhere by the National Safe Deposit and Vault Manufacturing Company of that city, under the patents of Messrs. Hough & Harper, of Pittsburg. This, also, has been carefully examined by the Commission, both in drawings and as built for safe-deposit companies in Pittsburg. This form of safe, or more usually vault, is built under patents of dates of 1884 and 1889, and is a very different system from that just alluded to.

The vault by these makers consists of a mass of blocks of chilled iron, of great size and weight, laid up very much as heavy cut-stone masonry is put together, but with ingenious and curiously arranged rabbets and dovetailed connections of block with block which seem to make the structure substantially a single mass. The external surfaces of these blocks are chilled to a depth depending upon their size and upon the quality of the iron selected for the purpose; so that it may be said that the exterior of the vault consists of a surface of armor an inch and a half or two inches in thickness, and of such hardness that it may resist successfully the cutting edge of any ordinary drill, and may be absolutely impervious to the cutting edge of any chisel. These blocks are of such size—weighing from three-quarters of a ton to several tons, according to location, the heaviest being placed where the vault would otherwise be most vulnerable—that their weight alone consitutes a serious obstacle to their removal, even if loosened by explosives. The joints are fitted by carefully shaping the blocks, giving them accurately smooth and plane surfaces and by grinding their irregularities off by means of an emory wheel, which is thought to be the only practicable way of even dressing them into greater accuracy of form, and of smoothing their surfaces and edges. The tonguing and grooving, and the dovetailing of block to block, and the final bolting of the whole by through bolts extending from top to bottom and from side to side, within the thickness of the 12-inch wall thus built up, is claimed to give the whole all the solidity of a single great casting. The key to the whole is the last block inserted, which makes the final step in construction, and which is secured from the inside by a strong system of special bolting.

In the Hough & Harper vault the door consists of a single enormous casting of iron, chilled on its exterior surface, and sliding when open, into a deep recess in the side walls. Its weight is 5 tons or more; its thickness 12 inches, and its strength probably all that is claimed for it or desired. It is carried on antifriction rollers. and is thus made to move with comparative ease. When closed it fits well, and the construction is such that we have not been able to discover a probably practicable method of attack from the outside. The system of locking is the automatic, which makes the use of spindles or other pieces passing through the door unnecessary, and evades that source of danger. The locks themselves are peculiarly arranged, being placed not on the doors as is customary generally, but upon the inside of the wall of the safe, adjacent to the door, and are inclosed in steel cases. The bolts pass into slots in the rear of the door. The opening is effected, in all cases of use of this system, by the action of a time lock, adjusted by the cashier or other officer entrusted with that responsibility. Two doors are commonly fitted to each vault, to insure absolutely against a "lock-out," a precaution which is advisable in all cases and with all constructions.

This vault construction has been too short a time in use to permit any experience to be had which can reveal its value in resisting the attacks of burglars by their usual and most effective weapons; and the Comission are unable to assert more than that it seems to be a promising method of vault-building. We do not see how the use of wedges could be successful in attacking it; the time required for drilling would seem likely to prove entirely too great to permit its being opened by any process involving that method of attack, and even the high explosives would appear to have little opportunity for mischief, even at the door, that usually most vulnerable spot. We are not prepared to say that this vault can not be opened by some ingenious application of a burglar's method and material, and in a burglar's time; but we have not been able to decide upon a promising method of attacking it by such means and in such time. If any vault of this make is opened,we should anticipate that it must be by attacking it at the door with explosives, as in the ordinary case. Just how the two will compare we are unable to say; but we are inclined to place this construction among the more reliable of known systems of vault building.

Where space is important, and land very valuable, it is possible that the thickness—1 foot—of the walls of this vault may introduce a question of relative costs, and where it is imperative that lightness shall come in as an element of importance, its weight becomes a matter of consideration; as it has more than double the weight of the heaviest of the vaults of common forms. Its parts are not, however, heavy enough to make this objectionable in building; as they may be carried into any place in which a vault would ordinarily be built, or through a window, without special difficulty. In other locations, this weight is an element of safety. Experiments made upon this material by the use of high explosives have been reported and published which give a very good idea of its strength and resisting power, in such masses as are here employed. In tests made (not by the Commission) at the works of the Griffin Car Wheel Works at Detroit, where vaults of this character have been constructed, the explosion of seven ounces of dynamite in three holes of, respectively, 3, 3½, and 5½ inches depth, and of 1½ inches diameter, and bored near the middle of the door made for one of these large vaults, produced no other effect than the "spalling" off of fragments on the edges of the holes. The drilling of the holes occupied, as reported, a total of forty hours, and destroyed 87 drills made of Jessop's "special" steel. The door remained practically, so far as could be seen, as strong and safe as ever. A set of photographs of this and other less severe tests has been presented to the Commission and are appended to this report (Appendix B) with other descriptive matter furnished by the proprietors.

In reference to this peculiar and interesting novelty in bank vault construction, the Commission, while unwilling to prejudge a case which must ultimately be settled by experience—and in which the tests must ultimately be finally made by experimenters of more experience and professionally more expert than even the safe-makers—are prepared to state that in our opinion, this construction is a perfectly practical and peculiarly strong one, and may undoubtedly be placed, in spite of the prejudice that will unquestionably be met by it, among the actually available systems for protection of securities. The enormous thickness and massiveness of its walls, also, will probably prove of advantage often, in cases of fire, giving the structure up to a certain limit, a fireproof character; although it will probably be found advisable to still further protect the contents by the use of fireproofing.

A considerable number of these bank vaults have been built for bank and safe deposit companies, and of these the Commission visited two and carefully examined their construction and finish. Both were in the city of Pittsburg, the one in the building of the Fidelity Title and Trust Company, the other in that of the Farmers' Deposit National Bank, both of which are large and well-known and substantial concerns.

The first of these vaults is a structure of the usual thickness—12 inches—as adopted by these makers, and containing some 500 tons of iron. Its doors, two in number, are of equal thickness with the walls and each in a single mass, weighing about 5 tons. They slide on friction rollers into recesses in the walls on either side, heavily reënforced to give ample strength at this the usually weakest point in such constructions. Both doors are secured by automatic bolting systems with time lock attached. The massiveness of the vault gives the impression of impregnability against burglar or mob and against either wedges or dynamite; but only time and experience can probably settle that. The same statements will apply to the vault of the second of the companies visited. The interior was commodious and well lighted from the doors, of which, as should always be the case, two were fitted as an insurance against a possible lockout. The work, so far as it could be inspected, was good, and the whole construction left on the minds of the Commission an unexpectedly favorable impression. The whole outcome of this visit was satisfactory, as giving new facts and opening new possibilities where it had not been expected that anything of importance would be revealed in the way of novelty.

The Commission would have been glad to obtain further information relative to the strength of roof, for example, to withstand the heavy load carried in its own weight, and any added weight that may accidentally or purposely be brought upon it, and as to the possibly vulnerable points undiscovered during their necessarily short visit.

The Corliss safe and bank vault, first mentioned above, the first invention involving the use of chilled iron to find actual place in the market and to become a regular article of manufacture in competition with the steel and iron constructions most commonly adopted, was studied by the Commission with even greater minuteness than the Hough system. Mr. Corliss has thus far built only safes of moderate size, and a special and ingenious construction of vault door. He has plans and models of his proposed bank vault, as intended to be built of chilled iron, and these are sufficiently well made and complete to enable the expert to satisfy himself in reference to any matters of form and method of construction. The safe, as built to-day, consists of a spherical shell of iron, chilled on its exterior of from 4 or 5 to 6 or 7 inches total thickness, of which the chilled and hard portion occupied the outer 2 inches. Within this shell is a "bugging," as it is denominated, composed of a set of cast-iron segments of sufficient thickness to permit the passing into them, in holes cast for that purpose, of a set of tool-steel rods, hardened as hard as fire and water can make them, and lying loosely in their places; the idea being that a drill, striking one of them, will be unable to penetrate the metal and, the rod, turning under it, will simply break the drill by taking it at such disadvantage, wedging the edge of the tool and bringing on it a lateral stress which is the more certain to cause fracture as the force is increased. The inventor is confident that the difficulties met with in the attempt to penetrate the exterior chilled shell alone will make it impossible to enter the safe "burglariously" in a "burglar's" time, but assuming this as a remote possibility, it will be found impracticable to drill further when it is thus reënforced.

The door of this safe consists of a sphere or an oblate spheroid of iron, also chilled on its exposed face, hollowed out to receive the locks and attachments of the bolting system, and fitted into the doorway, a circular orifice in the outer shell, by exactly turned and faced stepped joints. A turned surface may be made a more exact fit than any other form and actual contact and permanent pressure between the two abutting faces can be here secured more readily and certainly than in any ordinarily formed opening. The exterior faces, being in the chilled iron, are turned with special tools and the external part is finally brought to shape and fit by grinding. It is a very slow and costly operation, but a very accurate fit is insured and one which is intended to be made actually air-tight and metal to metal. The door is brought up to its place by pressure acting outward, and it is considered by the maker that it is practically impossible to either wedge it back and force it into the safe or to secure entrance by introducing explosives.

The only practicable line of attack, aside from this closely fitted joint about the door, would thus seem to be drilling the shell, which, being in a single thickness, presents no opportunity for piecemeal destruction. Of this safe it can only be said, as of all other forms in use, that, given time and good tools and materials, penetration is probably possible, but that the time and tools ordinarily obtainable by burglars may fairly be presumed to be insufficient for the purpose.

This safe is considered by the Commission one of the practicable and valuable devices for the protection of securities.

The lock is either a combination lock of good construction or the time lock with automatic unlocking arrangement. As customarily arranged, the destruction of the lock destroys the available means of access to the safe. The lock spindle is made of the best steel and so small that violent attack would simply break it and add to the difficulties of entrance; and the spindles used for manipulating from the exterior are so made that the explosion of dynamite against them, and at their extremities, accomplishes nothing, a fact illustrated by experiments made by Prof. Monroe, U. S. Navy, and by Lieut. Rodman, U. S. Army, and exhibited to the Commission. Double locks are employed to avoid the possibility of a lockout.

The bolting system is an interesting and important novelty. It consists of a lever combination, operated by the working spindles, which in turn acts upon a ring completely inclosing the door and fitting nicely both door and door socket in such manner that, when expanded into its place, it forms almost a continuous bolt around the door. The levers actuating the ring take hold of its two ends at a point where it is cut for the purpose, and either draw it together into the door or allow it to expand into the shell of the safe around the door, when, being half in the door and half in the door frame, as it may be called, it forms the strongest possible bolt. This flexible, elastic steel ring serves also to seal the joint, if other seal be needed than the nicely made fit already referred to. The whole is a well-contrived, ingenious, and novel system, as essentially a type by itself as is the Corliss steam engine in its class of inventions.

In attacking this safe there seem to be but two ways of forcing entrance, viz, by drilling the shell, and by explosives used at the door. Against the latter this safe offers more perfect security than any examined by the Commission, through the accuracy and perfect contact of its door joints and fittings. Against the former it has the security given by its outer chilled surface and inner lining—a security, in the opinion of the Commission, of real value. Precisely how, in its latest form, it compares in this respect with the more familiar kinds of safe it is impossible to say; but we are inclined to rate it very high, and the advantage of the impracticability of "peeling" it, is undeniable.

It was suggested to the Commission that it might be possible to crack the outer shell by exploding dynamite or other high explosive against it; but the Commission is satisfied that this would be entirely impracticable, and thus: This shell is necessarily made in two parts, in order that the door may be fitted to the inside; these two parts are secured together by a very accurately made faced and screwed joint of such character and strength that some millions of pounds would be required to break it apart, and this may be taken as ordinarily secure against any practically available method of burglarious attack.

To observe the effect of explosives upon the shell, one of these parts of an unassembled safe was taken into an open space, where no danger would arise to buildings or persons, and was exposed to repeated concussions by placing upon it charges of dynamite of increasing magnitude. The Commission saw it thus attacked with charges of 12 pounds of dynamite and more, and without breaking it. The surface was slightly burned, and fine hair-like cracks led off radially from the point at which the explosion was made, vanishing immediately from sight. The same charges exploded upon a safe of laminated plates of alternate iron and steel, as before noted—as commonly constructed—drove a hole directly through it. The Commission was thus amply satisfied on this point. The shock of the explosion broke windows some hundreds of yards away, and would, if it occurred in a bank building, presumably have wrecked the building and called the attention of a town to its cause. This method of attack is thus an impracticable one for this form of safe.

Drilling and the introduction of explosives into the safe are probably the methods of most promise in attacking this construction. The Commission greatly regret that in regard to the comparative merits of this safe and the standard system, in resisting this latter form of attack, it can only be said, as when describing the Hough vault, it is only possible to assert, with confidence, that the system here under consideration may be placed on the list of practicable and promising devices for protecting securities. The exact relative safety and strength of this as compared with the standard system must be ultimately determined by experience, but it must be rated very high. Given a drill hole in either of the known forms of safe or vault, and entrance is probably usually possible; but even then it may demand more than the time available for the purpose of completing the work. The Commission has seen a safe of good make, by a well-known firm, stand for hours unopened, with a large hole in its outer vestibule between the double doors, in spite of every effort of a skilled workman to complete the task of entering it; explosives being interdicted.

The plan proposed by Mr. Corliss for making a bank-vault is as nearly as possible that adopted for his safes. Requiring a much greater space within it, it becomes practically impossible to make it a single spherical mass inclosing a central chamber, as is the practice in making the safe; as this would involve the handling of such immense masses of chilled iron as would prove too heavy and cumberson to be economically employed, even if possible with any ordinary facilities, and the making, especially, of such enormous "chills" as to forbid this plan entirely. Mr. Corliss, therefore, proposes to build up his vault of a series of large rings of chilled iron several feet in diameter, perhaps 10 to 12, or even larger, each closely fitted to its neighbor, and secured, the one to the other, by being threaded upon internal screwed rings similarly fitted closely together, every part being drawn tightly against every other by this system of screw-threads. The edges of abutting rings are to be very nicely turned and scraped or ground, and the joints thus made as perfect as those in the safe. The ends of the great cylinders thus made, which may be of any desired dimensions, are of chilled iron, and the doors are placed in these ends or "heads," and are of similar construction to those already described as made for the safe. The vault is thus built up as a great cylinder, a dozen feet in diameter, 20 or 30 feet long, with a door at each end, preferably; and its whole exposed surface is made exceedingly difficult of attack, if not impregnable, by its 2 inches of "chill." The rings of which it is made up are of such diameter and weight that they may be transported, without special difficulty, on our railways, and the system is one which permits easy reconstruction when arrived at their destination. The whole rests upon a masonry foundation, but in a cradle so made that its whole exterior is exposed and subject to inspection at all times—an important provision. The whole work is intended to be machine work, and all to be lathe work; which means the greatest possible accuracy and minimum cost. The lock-work and bolt-work, the details in all respects, are intended to be similar to those which have been found satisfactory in safe construction.

While unable to base their judgment upon an inspection of such a vault actually constructed, the Commission see no reason to doubt that the whole plan is perfectly practicable, and that the result will be the production of a vault which will possess precisely the same qualities, on its larger scale, that have been observed in the safe now made. It will have an advantage in few and perfect joints; while it will not be as commodious or as easily adapted to extensive and convenient systems of interior boxes as the Pittsburg vault. Undoubtedly each will find its own special place and purpose.

While examining the specially interesting forms of safe, and details of safe construction, exhibited by Mr. Corliss, the attention of the Commission was called to his method of construction of doors for vaults of the usual standard construction. This door may be built up of alternate steel and iron plates, or sheets of hard and soft steel, as in the familiar constructions, where intended for burglar-proof construction, but where, as ordinarily employed, it is mainly for aiding in making the vault fire-proof, its special and most ingenious feature is a system of air-tight packing effected by the sliding of the bolts. These bolts are a set of bars laid parallel to the edges of the door, their sections being such that when thrown out, they form a frame all around the door, fitting one-half into the door itself, the other half of each bar sliding into a well-fitted groove in the frame around the door-jamb, and thus giving a seal against currents of air that might otherwise, in case of fire, sweep the flame into the cracks usually observed around such doors, and produce a warping and distortion of the door that would ultimately permit the entrance of sufficient heat to destroy the contents if not the vault itself, thus rendering it useless as a protection against fire, however good its general construction. The bars forming this framing seal are thrown out by a set of wedge-shaped pieces at the corners which also serve to seal those otherwise unprotected points. The whole arrangement is an admirable one, used as a system of bolting, if for no othor purpose, and the Commission think it one which could be incorporated into the construction of all vaults and with decided gain, as compared with the common constructions.

The recommendations of the Commission, after making this briefly described but somewhat extended investigation, are substantially in accord with those already made by the officers of the Treasury Department, so far as the general subject is concerned. There seems no question that the vault capacity of the Treasury itself, and probably at some of the subtreasuries and mints, is insufficient for present needs and likely to become still more inadequate as time goes on and the country grows richer and concentrates more and more of its wealth in the hands of the Government. Immediate extension is desirable and economy dictates that this extension be so effectively made that further expenditure in this direction may not be required for some years, if for a generation. Having in view, however, the fact that inventions and improvements are constantly and rapidly going on, it may seem advisable that the shorter rather than the longer period taken as a limit be here adopted. It may perhaps be assumed that reconstruction is likely to be made economically advisable as often as once in ten or fifteen years at most. With such enormous wealth concentrated in one building as is seen, at this moment, in the U. S. Treasury, any expense and every provision of modern skill and ingenuity may be considered as justifiable and desirable in its protection. We would therefore advise the immediate construction of new vaults to such extent as will give ample space, not only for the required deposits of to-day, but for at least all requirements for ten years to come; the adoption throughout of the best modern construction of vaults, walls, and doors, the most perfect systems of locking and bolting and, in short, such plans and such construction as shall make the latest vaults constructed for the Government the finest and most reliable that contemporary skill and invention can produce. The most perfect constructions and the finest workmanship, the most impregnable walls and the most excellent locks that the inventors and manufacturers of the United States can produce—unquestionably the best and most admirable in the world—should be found in the Treasury of the United States and its accessory departments. Differences of cost between the best and the less desirable, in this instance, at least, are of little moment. If the adage that the best is the cheapest is in any case true, it is certainly true here.

The contracts, in this case, are so desirable in themselves, however, and the opportunity to place representative work in so important a position of such great value, that it should be possible, by a properly arranged system of advertisement and specification, with suitable provisions for inspection, and acceptance or rejection, to secure the most perfect of known constructions at reasonable cost.

In the opinion of this Commission it will be wise to replace every vault in the Treasury Department, as early as practicable, with more modern and safer constructions. It may not be advisable to go to the expense, and to accept the risk of making all these changes at once, but it is advised that, each year, some work be done, beginning with the first and most extensive alterations already proposed by the officers of the Department, and continuing the work until it is completely finished and every dollar in the Treasury made as safe as science and art can make it. Vault No. 1 has absolutely no value as a protective construction. It is only its location and its guard that make its contents tolerably secure. It should either be completely lined at the earliest opportunity or a new vault constructed elsewhere to receive its contents and this structure removed to make place for something of real value. Meantime, it should be not only systematically guarded, but every possible approach, visible or concealed, should be kept under most thorough and unintermitted supervision, with frequent and complete inspection. Vault No. 2 should be retained for use in the preservation of the most important deposits while others of greater security are under construction. Vaults Nos. 3, 4, and 5 should be removed to make place for new vaults, perhaps one being taken at a time, until all are replaced. These constructions are at this time most discreditable to the Government and Treasury Department. Their safety comes not of their own strength, but of the efficiency and strength of the guard placed in charge of the Treasury; and their value as a means of protection is simply that of a resistance which may retard the entrance of an attacking party sufficiently to permit the reinforcement of the guard, if required, by a larger force.

Very much the same remarks apply to Nos. 6, 7, and 8, all of which fall far short of what should be expected where millions of dollars, worth of securities are to be cared for. No. 7 is that used by the division of national banks, and is reported by the chief of that division to be already too small for the purposes of the Department, and is stated to be likely to be more than crowded in a very short time. This is a vault which should be especially commodious for the purpose of securing convenience of storage and of access, and should be well fitted up with lock drawers and cases of sufficient number and magnitude to answer the purpose of this division for a dozen years to come. This is an imperative matter, as the trust funds and bonds here held are not the absolute property of the United States, and their proper separate storage is essential to prevent confusion and troublesome, if not seriously costly, mistakes.

The four safes in use in the National Bank Redemption Bureau are a generation old, and vastly inferior to those to-day considered desirable by the smallest country banks, or even the most modest of country merchants. They should be immediately displaced by either the best of modern constructions or by a vault of greater capacity and vastly better make. The remarks here made relative to the protection afforded by the safes and vaults of the Treasury Department are known to apply, in some degree at least, to the subtreasuries, and it may be found that they may also apply to some or all of the United States mints. It is advised by the Commission that reports be obtained from each in complete detail, and their condition very carefully ascertained, with a view to making them satisfactorily safe depositories of Government funds and securities.

The precise construction to be adopted should be decided upon by the officers of the Treasury Department after careful consideration of the facts which have been given in this report and in consultation with experts familiar with them. It is presumed that the Department will not feel safe in departing far from the now well-recognized and standard constructions, and that, in the determination of the precise constructions to be called for it will be thought best to follow closely the advice of its experts. This Commission would advise, however, that all vaults intended to hold any securities or cash that might be readily negotiated or put into circulation be made at least as heavy and strong as the best of these constructions now adopted by the largest and most responsible of the great safe-deposit companies and the largest banks of the great cities. Heavy 1 inch at least, 2 if practicable, alternate iron and chrome steel-rolled plate, and the best soft steel worked in with them, should be built into the side walls, not less than 4½ inches in thickness, and the doors should be not less than 6 inches. If franklinite is admitted, as may be perhaps desirable, an extra inch should be allowed to accommodate its excess of thickness in the single plate. The Commission consider its presence an advantage; but would not allow any important difference in price, as it is comparatively a cheap material, and its use involves some loss of nicety of internal fitting, which would to some degree tell against it.

In the specifications for the doors it is suggested that, costs being nearly equal, the system of Mr. Corliss, as applied to his fireproof vaults, might be advantageous as an excellent method of bolting and as giving a comparatively air-tight seal. The doors should, in our opinion, always be two in number, and should be fitted with double or tripple time locks, and either a double combination lock or, preferably, a double automatic system. The locks of the Yale and Towne Company and those of Messrs. Sargent & Greenleaf are both obtainable in either arrangement, and, as submitted to the Commission, seem to represent the most perfect possible design and workmanship. No other forms have been presented for examination; but the Commission is informed that there is an ample variety of such devices in the market from which to select in case of difficulty on the score of prices.

It is advised that the specifications for such vaults as may be authorized of these standard forms be prepared for the Department by experts, in consultation with the Treasurer and the Architect of the Treasury, and that, after public advertisement of the customary form and period, bids be received, an essential provision being that all material must be inspected, tested, and *formally passed by the inspector* appointed by the Department before being introduced into the construction, and that the workmanship must be similarly inspected and certified to be, in every respect, the best in quality and fully up to the standard of first-class work of the very best makers. Rejection should be provided for at any and every stage of the work, or after completion, should any defect be found.

The soft steel employed should have a tenacity and ductility corresponding with the specifications of the U. S. Navy Department for boiler plate, and the hard chrome steel or other used in the laminated plates should have the hardening qualities of the best tool steel, while the plates made by welding these hard and soft sheets together should be sound and free from lamination throughout, and, when fitted in place, perfectly smooth, straight, and true. All bolting should be done from the inside, and in such manner that it will be impossible to break their hold from without. All corners should be guarded and a welded framing should be made to inclose the whole system of plating, carried along and around all corners and all edges.

The fitting of all doors should be perfectly smooth, air-tight, and impenetrable by either an air blast or by fluid explosives. Bolts should have bearings of large area of surface contact, and should be impossible of springing either by the presence of a loose fitting or by crushing their bearings on the frames. They should fit their sockets pefectly and snugly, without jamming or bringing any friction resistance upon the unlocking mechanism. All locking and bolting arrangements should be duplicated, and all time-lock mechanisms should be so constructed that the failure of any clock movement should not incur danger of a lockout. The use of two independent doors in each vault, as above proposed, will give security, also, in this respect.

The number and various character of the vaults to be required to put the Treasury Department in a satisfactory condition of security is such that it might otherwise be considered inadvisable to introduce any but long-known and well-tested forms of vault, but, considering the nature and extent of the investigations which have been made of the material and the methods of construction adopted by the builders of chilled-iron safes and bank vaults, and in view of their own careful observations, this Commission is constrained to advise the introduction of at least one of each of the two forms given of the later construction as above described. In a position like that of the specie vaults, the weight of these structures, with their immensely thick walls, is no objection at all, and their construction in that locality is a matter of easy engineering. Should the Department propose further to continue the use of the *safes* as auxiliaries to the vaults in either of its bureaus it is suggested that a trial be made of this type, with a view to ascertain whether their use will be found as convenient and practically satisfactory as the more familiar kinds. The Commission do not think that there now remains so much of uncertainty as to their safety as to make this course one in regard to which any hesitation need be felt. They regard these constructions as practical and probably in some respects peculiarly safe.

The plan here proposed, of advertisement, building to a specification, and inspection and supervision by experts appointed to represent the Government, will undoubtedly, give good work in any case and at fair prices.

The commission also advise the very thorough fitting up of all the offices of the bureau of the Treasury Department in which business is done with the public, or in public view, with every usual provision against sneak-thieving and assault during working hours. In this respect the Department is very deficient. It is a matter of insignificant expense and should be immediately and very completely done. The proposal to use electric protection should receive careful consideration.

The specifications appended to this report are given simply in illustration of the forms and details of good examples of recent construction, and as illustrating what are considered to be good specifications, as independently written by experts and as approved by the best builders of the time. For the purposes of the Treasury of the United States the Commission would suggest making the outside plates as large and as heavy as they can be obtained from the makers. There seems no reason why the soft plates, at least, should not be made as large as any of the enormous boiler plates in common use in our Navy and elsewhere, and there seems to be no reason why, by sending the material to the plate mills, the laminated plate should not be obtained 2 inches in thickness as well as 1 inch, now the maximum for such "compound" plates.

We would propose that, before finally making up the specifiations, the maximum size and thickness of plates at the time obtainable be ascertained. Impregnability is now simply, as in building armored ships, a matter to be determined by the limits of allowable and wise expenditure. If the exterior be composed of iron or soft steel, the plates should not be less than 5 feet in width and should have a length sufficient to reach from top to bottom of the structure, and should then be well secured by rabbeting in the angles at edges and corners of the vault. Very probably it may prove practicable to obtain sheets as large as can be taken to the site chosen for the vault through the doors or windows of the building. There will be no difficulty in obtaining from the makers of plate plain steel plates of any desired quality and of any desired thickness. The thicker the exterior plates the safer the whole, and this safety increases in rapid ratio with increasing thickness. The Commission would suggest the possibility that the circulation of this report, or of an abstract of it, among safe and vault makers and makers of plate may lead to the construction of an entirely new specification with great advantage to the Government, and to the banks of the country as well, by thus bringing into the market better qualities, heavier plates, and the production in this manner of a better specification and a stronger construction. Specifications may be made, should the Department desire it, subject to the approval of the Commission.

In relocating vaults we would suggest their arrangement in such manner as will permit their inspection on all sides at all times.

Very respectfully,

ROBERT H. THURSTON,
THEO. N. ELY.
F. A. PRATT,
Commissioners.

Hon. CHAS. FOSTER,
Secretary of the Treasury, Washington, D. C.

RECORD OF PRELIMINARY EXPERIMENTS WITH HIGH EXPLOSIVES, BY PROF. CHARLES E. MUNROE AND LIEUT. SAMUEL RODMAN, JR., U. S. ARMY.

WITH APPENDIX RELATING TO AND ILLUSTRATING MECHANICAL BURGLARY.

The following series of experiments with high explosives were made by Prof. Charles E. Munroe, and by his assistant, Lieut. Rodman, U. S. Army to determine—

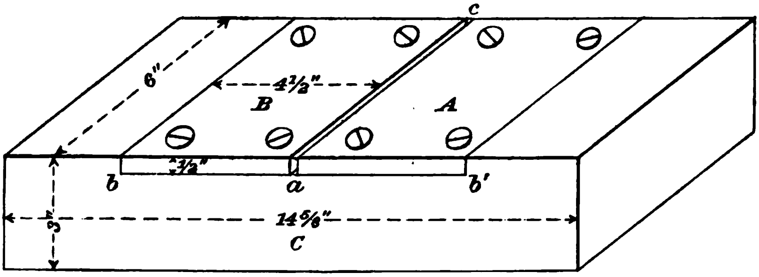
***First.* The value of the laminated system of safe and vault construction as a security against the use of high explosives.**

***Second.* The value of the Corliss system of safe and vault construction as security against the use of high explosives.**

EXPERIMENT WITH BOLTED PLATES (LAMINATED SYSTEM).

The following experiment was made and reported upon by Prof. Charles E. Munroe at the Torpedo Station, Newport, R. I., upon a test specimen described below and shown in the accompanying photograph No. 1:

The test specimen consisted of a block of wrought iron 6 by 3 by 14⅝ inches, in one lateral face of which two laminated plates 6 by 4½ inches by one-half inch were let in flush with the surface, each being fastened by four one-half inch screws as shown in the figure.



The crevice (*a*) between the plates A and B was 0.024 inch in width, and the crevices, *b*, *b*' were each less than 0.01 inch in width.

The explosive charge was inserted in the space (*a*) by crowding it in with a thin strip of tin, the edges were filled with putty, the 5-force blasting cap used was laid on the face of the crevice (*a*) over and in contact with the charge, and a bag of sand was laid on this before firing.

EXPERIMENT 1.—Fifty grains of explosive gelatin were packed in (*a*) and fired as described above.

Result.—The crevices *b*, *b*' were closed up and the corner (*c*) of plate A was raised about 0.01 inch.

EXPERIMENT 2.—Sixty-five grains of explosive gelatin were packed in (*a*) and fired as above.

Result.—The corner (*c*) of plate A was raised about one thirty-second inch and the two screws on each of the plates A and B adjacent to the crevice (*a*) were loosened.

EXPERIMENT 3.—Ninety-three grains of explosive gelatin were packed into the crevice (*a*), care being taken to force as much as possible through the crevice (*a*) under the corner (*c*) of plate A. The charge was tamped with sand instead of putty, but otherwise the conditions were as in experiments 1 and 2.

Result.—Plate A was torn completely off, the four screws being sheared off at the points where they entered the block C. The ends of the screws remaining in the block C were so loose that they could easily be extracted with the fingers. The corner (*c*) of plate A was distorted. The screws in plate B were loosened. (See photograph No. 2.)

The last experiment required for the entire operation (from the beginning of the charging with the explosive to the tearing off of the plate) but fifteen minutes. With practice in the manipulation I believe that the three firings could have been effected in forty-five minutes or less.

The firing took place in an underground passage. A person, who was unaware that the experiment was being made, stood on the ground above the passage and about 20 feet from the test specimen when the final and heaviest charge was fired. This bystander heard the report but it appeared so dull to him that he imagined it to come from a point more than a mile away.

My opinion is that this test specimen represents a much more resistant structure than would be found in a safe constructed on the laminated system, owing to the block C being so massive, and to the plates A and B being recessed into it, thus making it difficult to shear the screws off. The joints, too, were closer than frequently obtains in the structures in use.

I hence conclude from these experiments that the laminated structures in common use can be destroyed as easily, if not more easily, than this was.

CHARLES E. MUNROE.

APRIL 19, 1891.

EXPERIMENTS WITH CORLISS SPINDLE.

The spindle was finished and complete, but it was mounted in a cylindrical block of wrought iron instead of a safe, for convenience in testing here, the method of mounting and fit being such as obtains when the spindle is in place in a safe. (See photograph No. 3.)

The attack was made upon the square aperture in the end of the spindle, the aperture being five-eighth by five-eighth by three-fourth inch deep.

In each case the spindle stood vertically for convenience in loading only. The firing was effected by means of detonators, containing 35 grains of dry mercury fulminate, which were buried in the center of the explosive charges, and the hole was tamped by corks which surrounded the upper end of the detonator case and rested upon the explosive charge and were firmly lashed in place by means of wire lashings. The charge and detonator in each case filled the cavity.

EXPERIMENT 1.—One hundred grains of explosive gelatin used.

Result.—Slight surface cracks developed from each corner of the rectangular opening of the spindle, nickel plating shaken off in spots, the faces of the aperture in the spindle were underscored and nut on end of spindle loosened.

EXPERIMENT 2.—One hundred and five grains of explosive gelatin used.

Result.—Cracks above noted lengthened and deepened and two smaller ones starting from one wall of aperture were developed; nut loosened.

EXPERIMENT 3.—One hundred and ten grains of explosive gelatin used.

Result.—Three of the cracks noted above as running from corners of aperture were extended to within one-eighth inch of cylindrical surface of spindle. A prismatic fracture developed at one of the angles of the aperture. Nut again loosened. (The nut was screwed up before each charge was put in.)

EXPERIMENT 4.—One hundred and fifteen grains of explosive gelatine used.

Result.—Three cracks above noted extended to cylindrical surface of spindle, all widened sufficiently to admit of a thin knife blade being inserted in them. Nut loosened.

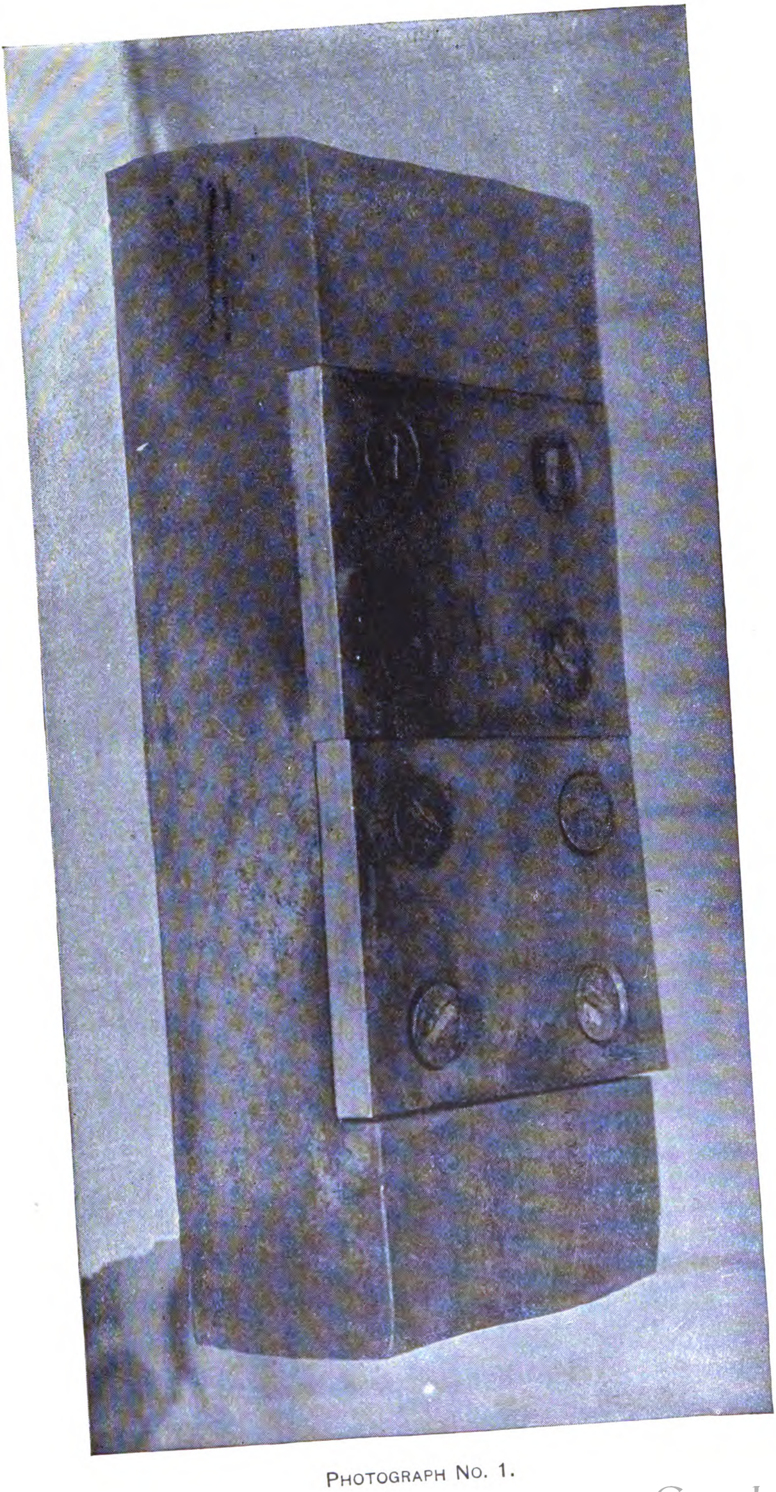
EXPERIMENT 5.—Three hundred and three grains of moist fulminate of mercury used.

Result.—A piece of metal, having on the face towards the charge an area of one face of the aperture, was splayed off. The cracks at the remaining two corners were enlarged. The lower end of the spindle, which projected three-fourths of an inch below the nut, and which at this point was seven-eighths of an inch in diameter, was broken off clean, and the *underscoring* became quite marked, while the remaining walls of the aperture were much bruised. The accumulated effect of these repeated firings simply tended to break off the head of the spindle nearly flush with the bottom of the aperture, and no marked indentation was produced into which further charges could be introduced, so that the stability of the spindle remained unimpaired. (See photographs Nos. 4 and 5.)

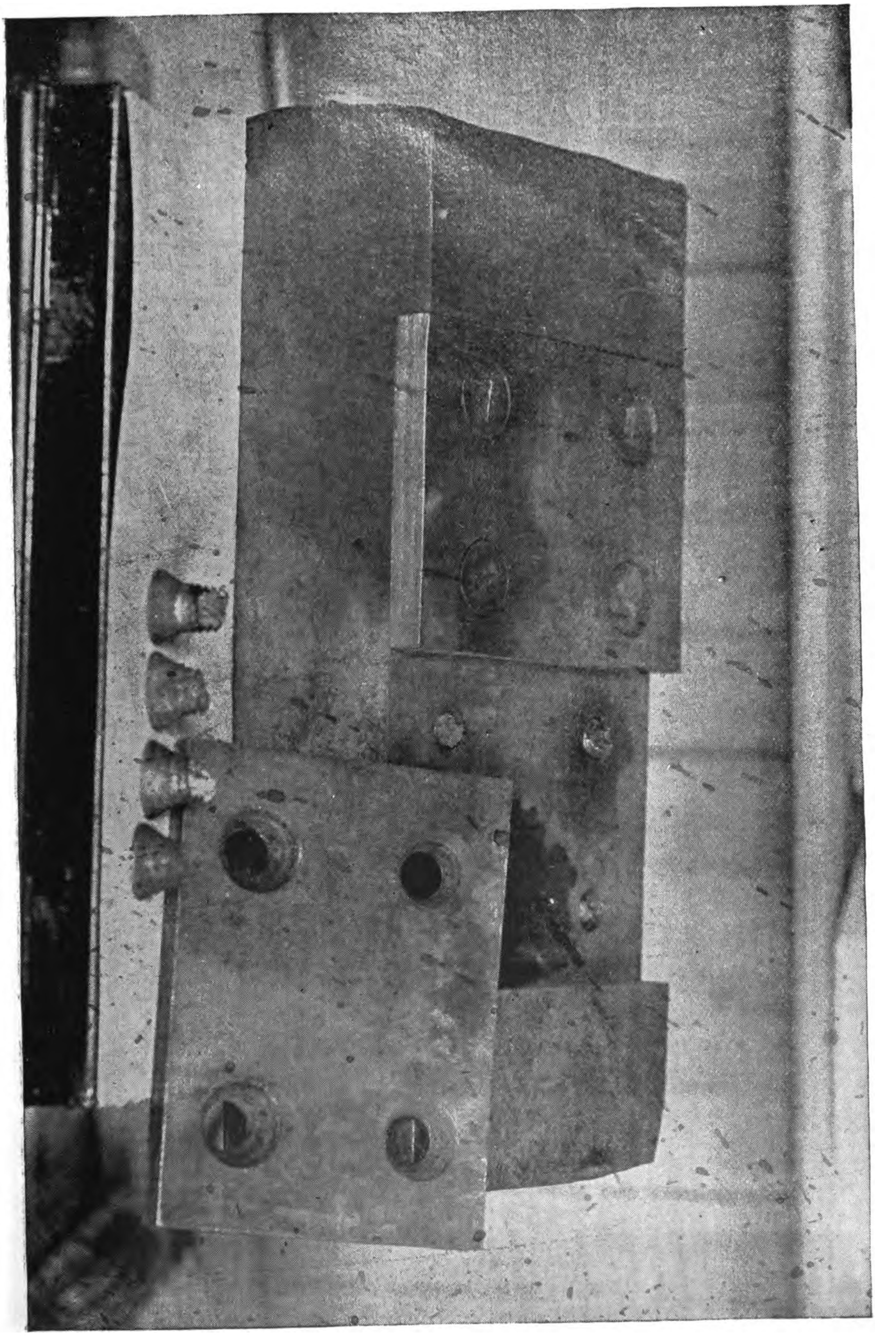
From the results obtained in these experiments I am of the opinion that the Corliss safe can not be opened by attacking the aperture in the spindle in its present form, by means of high explosive charges.

CHARLES E. MUNROE.

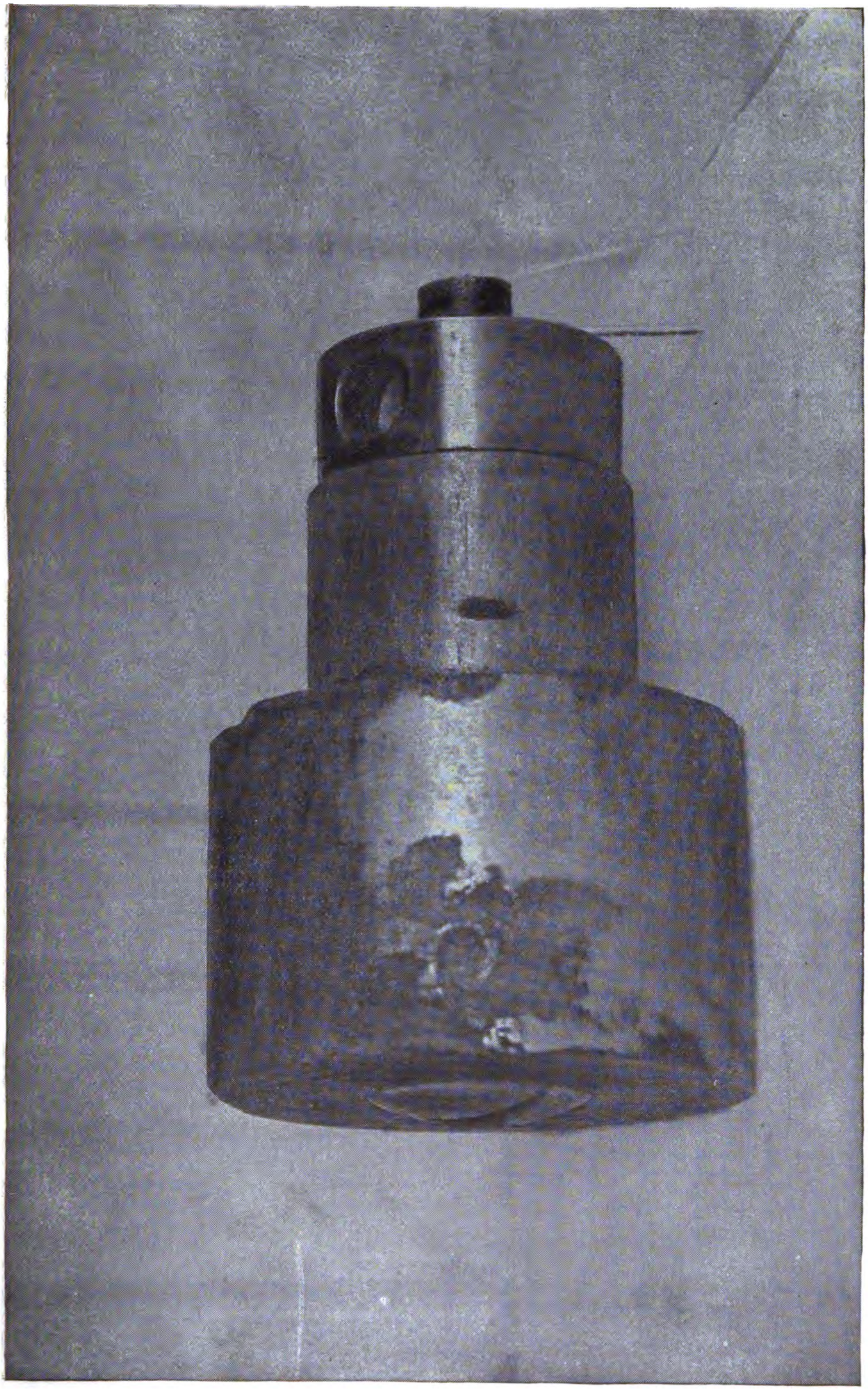
NEWPORT, R. I., *May 25, 1891.*



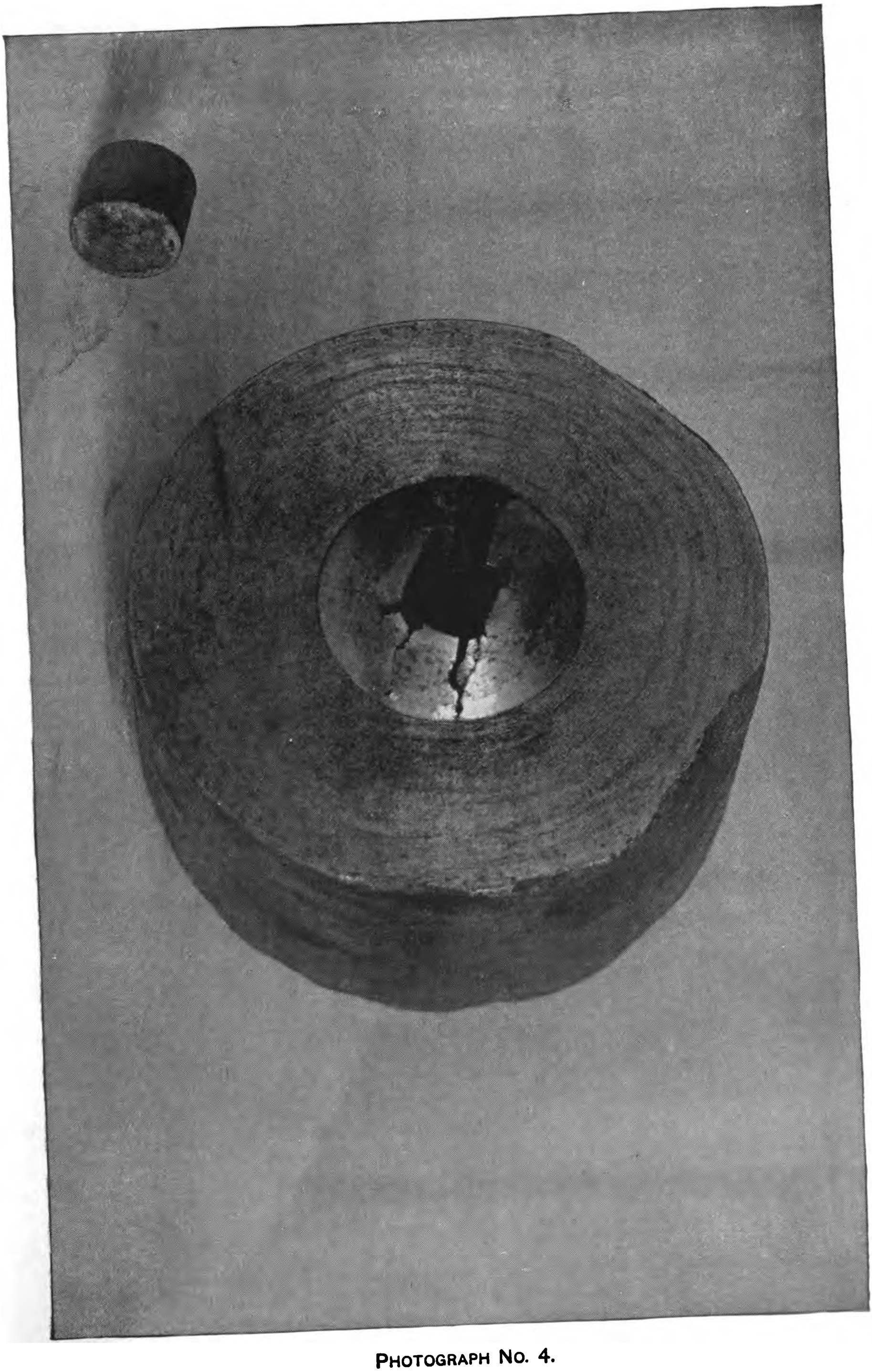
Photograph No. 1.



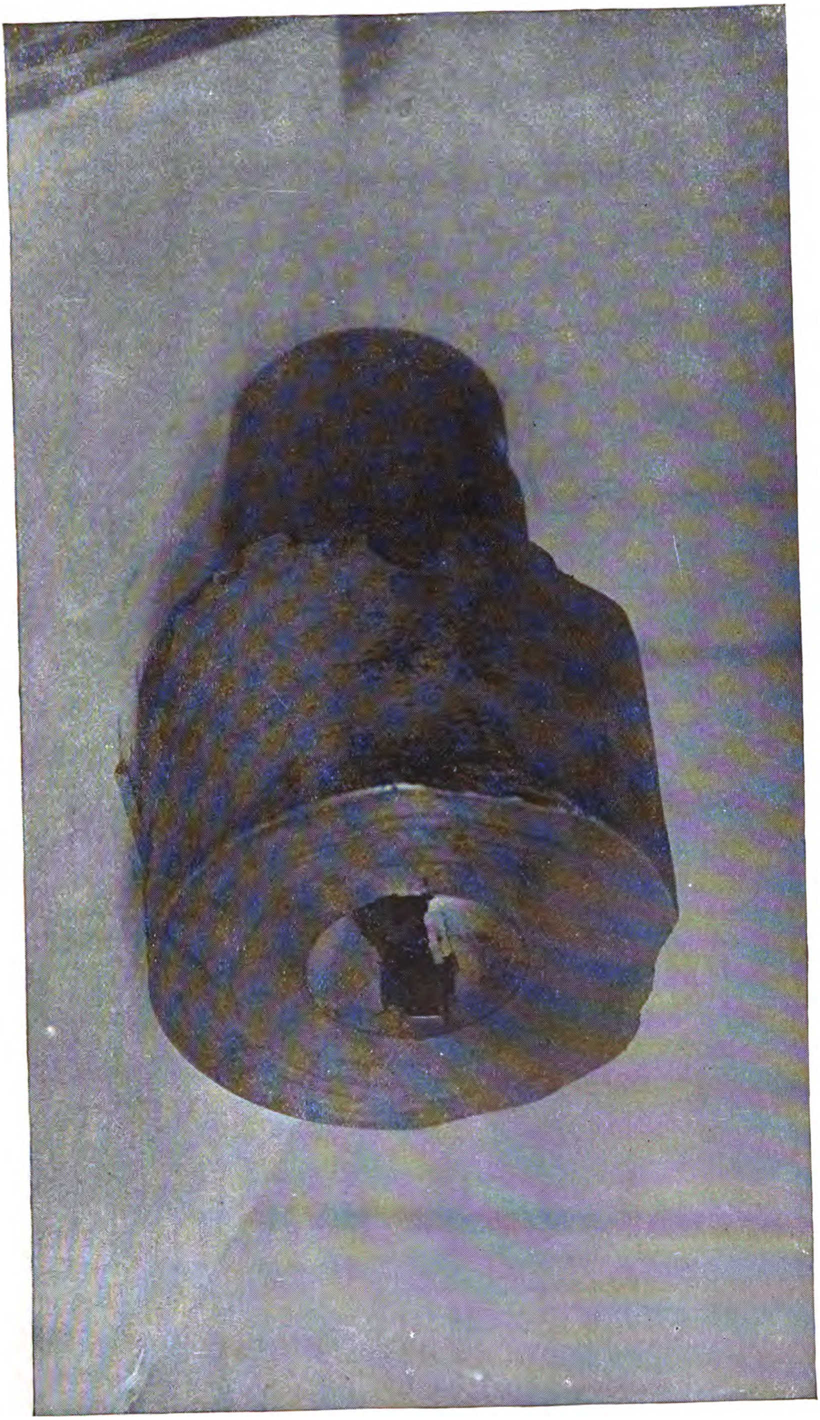
PHOTOGRAPH NO. 2.



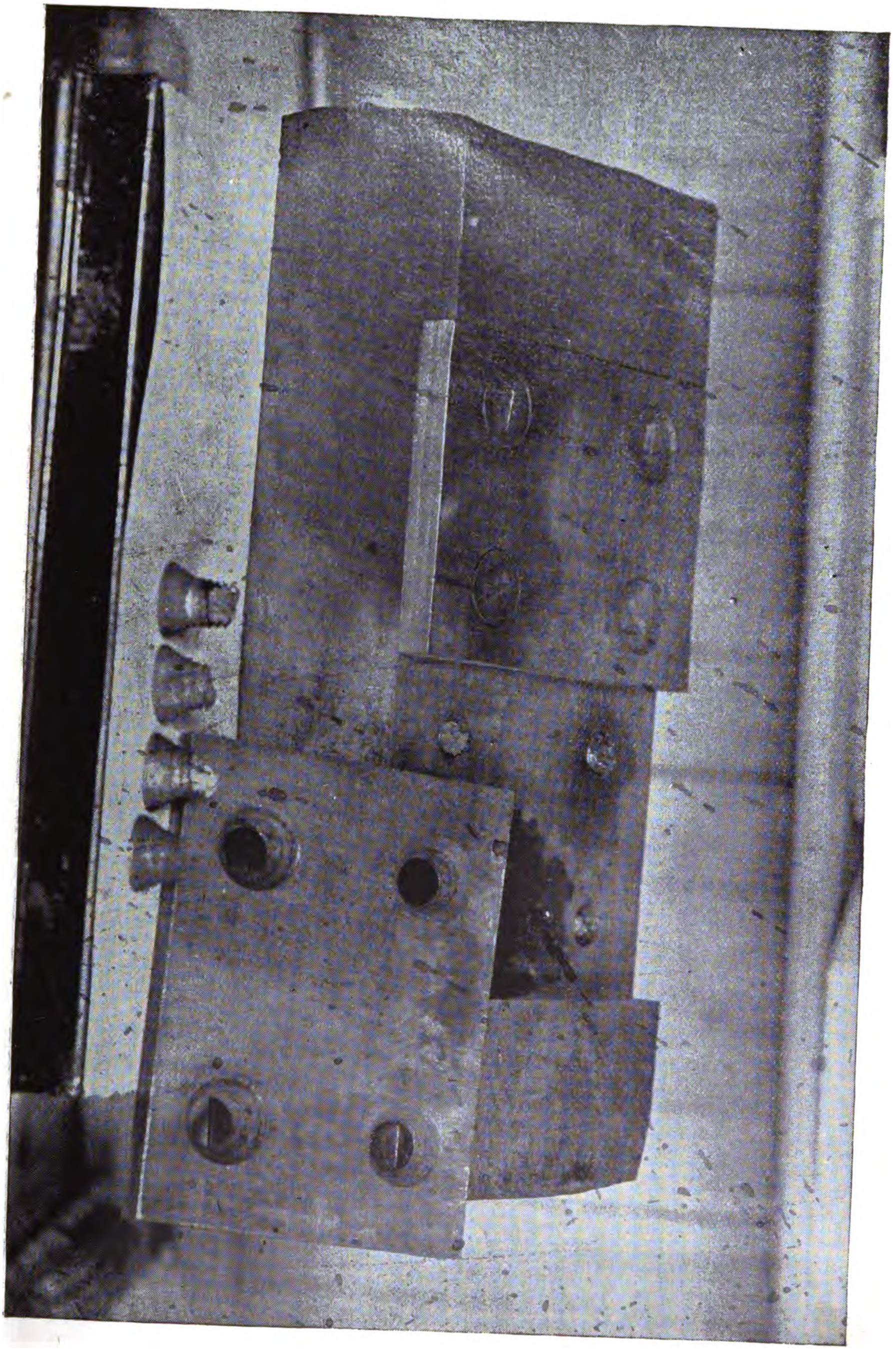
Photograph No. 3.



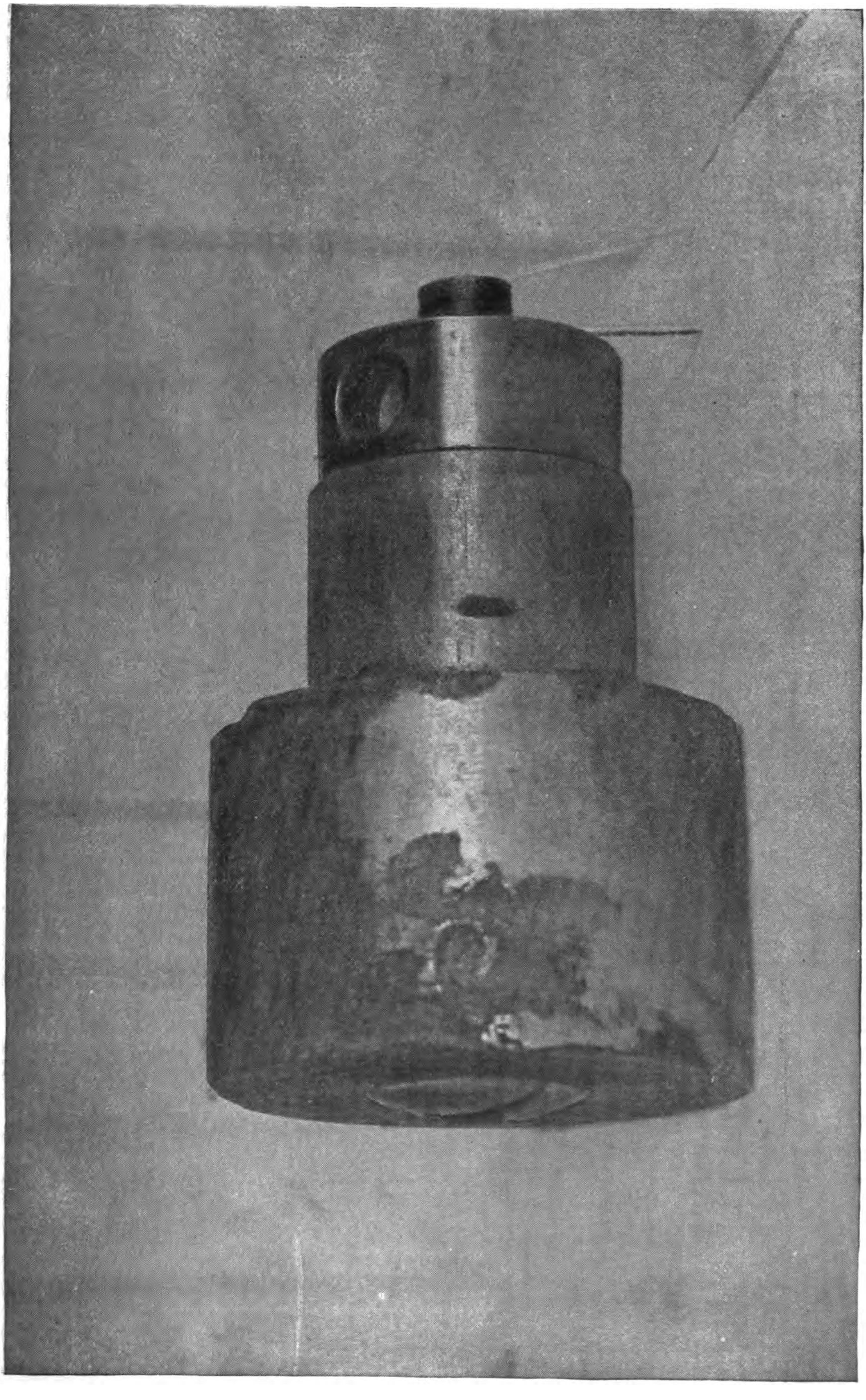
Photograph No. 4.



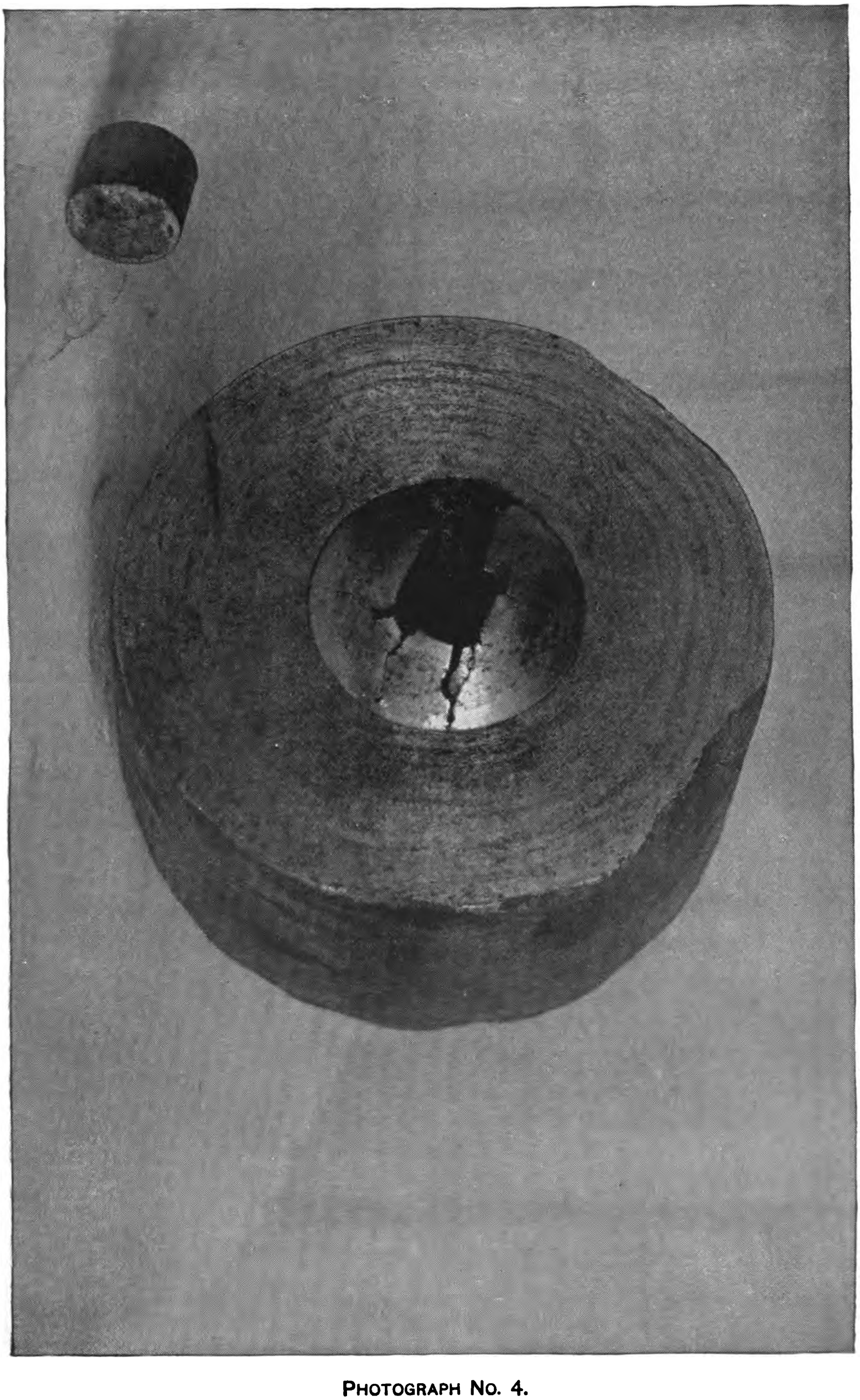
PHOTOGRAPH No. 5.



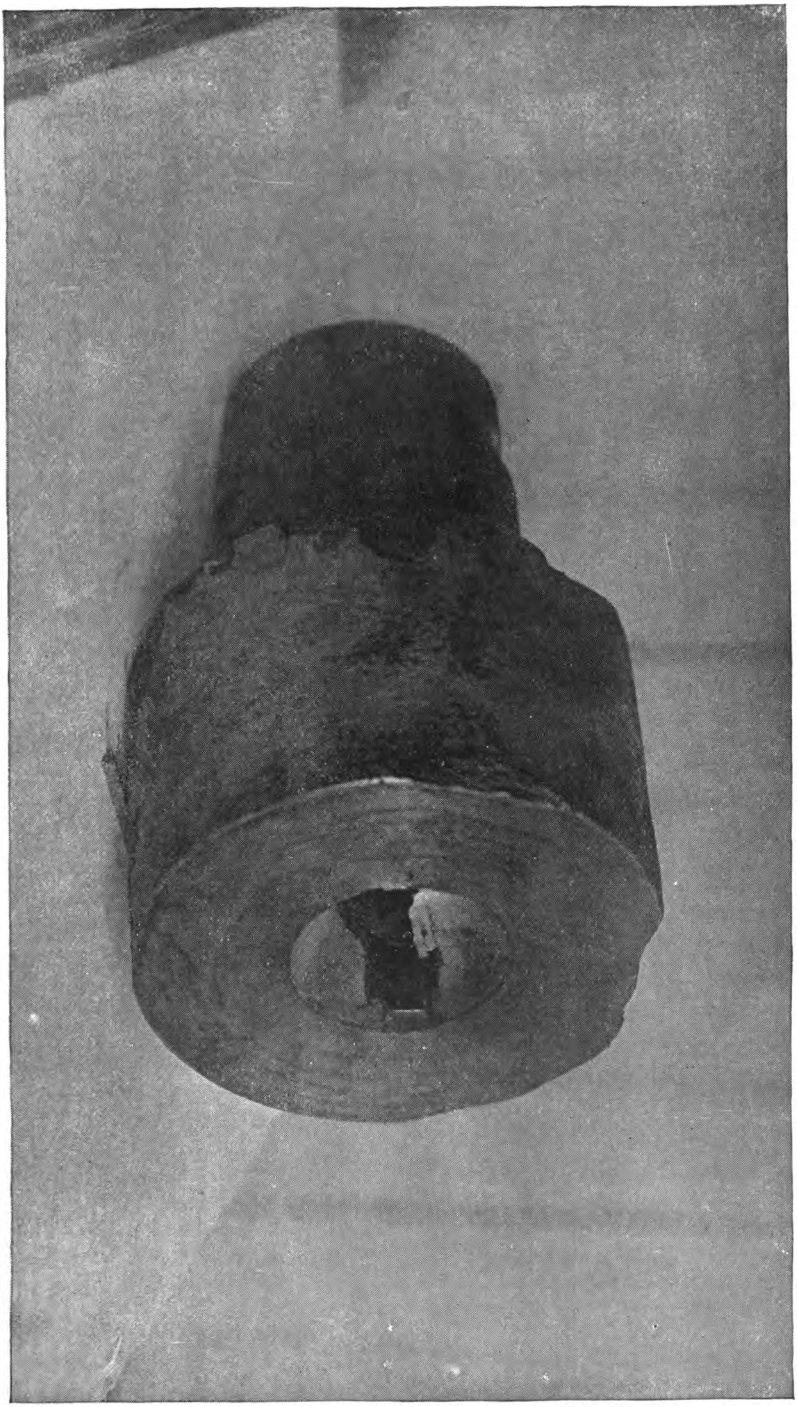
Photograph No. 2.



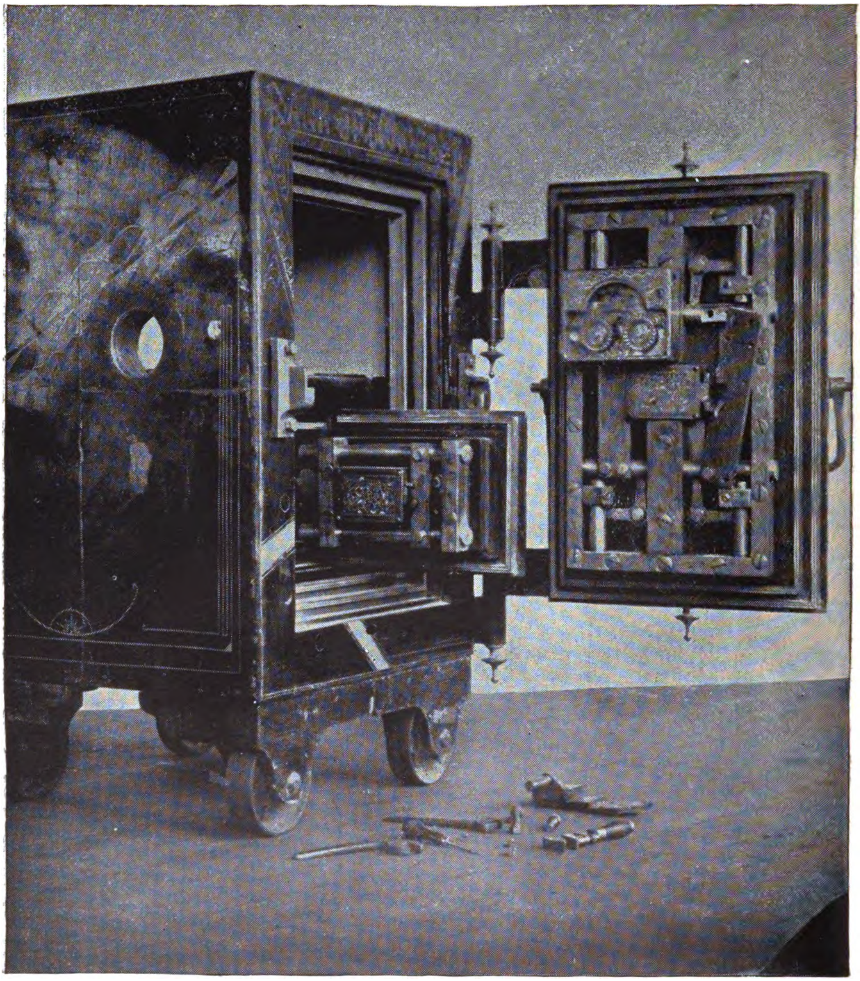
PHOTOGRAPH NO. 3.



PHOTOGRAPH No. 4.



Photograph No. 5.



Diebold Safe. Having been Previously Opened by Cutting a 4-inch Hole through the Body.

AUBURN, R. I., *December, 1891.*

EXPERIMENTS WITH HIGH EXPLOSIVES AT THE WORKS OF THE CORLISS SAFE AND VAULT DOOR COMPANY.

A square safe made by Diebold Safe and Lock Company, Ohio, was used in the first nine experiments. (See photograph.)

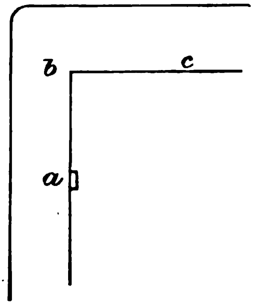
The safe measures 3 feet ½ inch high, 2 feet 6 inches wide, and 2 feet ½ inch deep, and is composed of six layers of ½-inch plates. First plate is of welded steel and iron, solid angles. Second plate is of wrought iron. Third and fourth plates are of steel, made up of horizontally laid strips of varying widths, the joints of one set being covered by the plates of the other. The fifth plate is of wrought iron. The sixth plate is made up of horizontally laid wrought-iron strips with solid angles. The plates are held together by large conical screw bolts, and by smaller bolts, as is usual in laminated structures.

The door measures 2 feet wide by 2 feet 6 inches high, and is about 4 inches thick, made up of plates as follows: First plate is of welded steel and iron, and is three-fourths inch thick. Second plate is of wrought iron, one-half inch thick, tongued and grooved on edges. Third plate is of welded steel and iron, one-half inch thick. Fourth plate is of wrought iron, one-half inch thick. Fifth plate is of welded steel and iron, one-half inch thick. Sixth plate is of wrought iron, one-half inch thick. Seventh plate is of welded steel and iron, one-half inch thick, tongued and grooved on edges. The bolt work is supported by a heavy steel frame fastened to inside plate of door by large screw bolts.

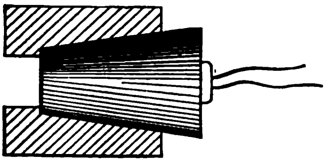
Inside the safe is a burglar chest consisting of a top and front set in the bottom of the safe. Its side, bottom, and back are the sides, bottom, and back of the safe.

FIRST EXPERIMENT.

Sixty grains of explosive gelatine were packed in the crack between the door and the jamb, as shown in the figure, from *a* to *b* and from *b* to *c*, *a* to *b* being about 1¼ inches and *b* to *c* the same. A thin wedge driven in at *a* had opened the crack *a b* about one-sixteenth of an inch; crack *b c* was of the same width.



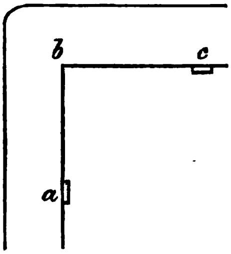
A fulminate of mercury detonator was used as the exploder. The detonator was inserted in a hole made through a cork. This cork was arranged as follows: In slits cut in outside of cork were placed two strips of tin in such a manner that when these were inserted in the crack between the door and jamb they would hold the cork and detonator in it against the gelatine. (See Fig.)



In this case the cork was so placed as to bring the detonator against the crack at the point *b*. No tamping was used, and when the detonator was fired the gelatine was not exploded, but simply blown out, pieces being subsequently picked up from the floor. It is evident that the gelatine had been too loosely packed.

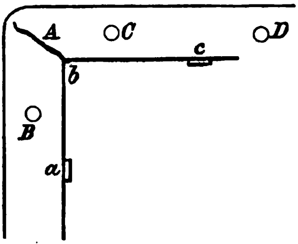
SECOND EXPERIMENT.

A small wedge was now driven in at *c* (see Fig.), opening the crack above the door about one-tenth of an inch, and at a distance from *b* of about 3 inches.



In the crack from *b* to *c* were packed 100 grains of explosive gelatine. Detonator held in cork plug was placed about midway between *b* and *c*. Putty was used as a tamp and an iron plate was laid up against the cork plug.

The gelatine detonated, and the crack A was made in first plate of door jamb, as shown in the figure,



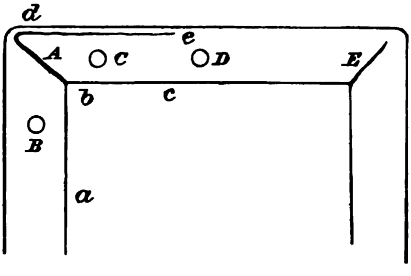
and plate lifted one-fourth inch on both sides of crack and separated from second plate for a distance of 6 or 7 inches along the top of and down the side of the jamb. The wedge at *c* was blown out. Three conical bolts at B, C, and D were broken off to a depth of 2¼ inches, leaving three holes, tapering from 1 inch in diameter at outside to seven-eighths inch at the bottom. The door was not started, but the crack beween door and jamb was widened to one-eighth inch.

This experiment shows that with a small initial charge of high explosive a good start for subsequent operations can be made, and the noise of explosion is so small that when performed in a bank or bank vault it would probably not attract the attention of any one passing in the near vicinity.

THIRD EXPERIMENT.

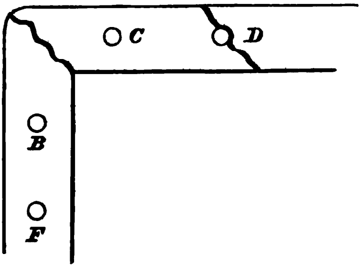
One hundred and twenty grains of explosive gelatine were packed in crack *b*, *c*, just as in second experiment, and cork plug holding detonator similarly placed. An iron plate was laid on top of the safe and projected over the front. Another plate was placed against the cork plug. Putty was used to tamp the gelatine.

As the result of this explosion the crack A was extended to *d* and along top of first plate of door jamb to *e*, a distance of about 5 inches. This part of the first plate of the door was bulged out about 3 inches and the side plate about the same. Crack E was made as shown in the figure and extended through the plate.



FOURTH EXPERIMENT.

In this experiment the two bolt holes B and C were filled with Atlas powder, grade A, and tamped with sand; a detonator was placed in each charge, and they were connected up in parallel.



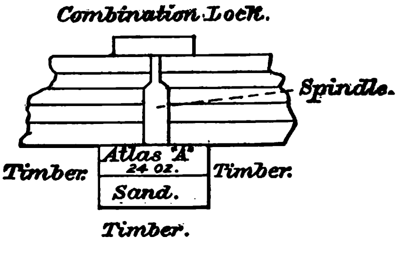
The amount of Atlas powder used was 2⅜ ounces.

As the result of this explosion one-half of the first plate of door jamb above the door was thrown off a considerable distance. The plates behind it were bulged out considerably, showing that the gases of explosion had penetrated between them. Another conical bolt, F, was broken off, as in the second experiment.

FIFTH EXPERIMENT.

Before proceeding any further in the line of experiments just conducted the combination knob was removed and an attack made upon the spindle of the door in the following manner:

A wooden box about 4 inches square was divided into two equal compartments by a thin wooden partition. Into one-half were packed 24 ounces of Atlas powder, grade A; into the other a tamping of sand, and the whole was placed with the Atlas end against the door spindle. It was supported in this position by a heavy block of timber, and other blocks were placed against it on the sides and back. (See fig.)



As the result of this explosion the spindle was driven in about one-eighth inch. The combination lock was somewhat loosened, but not knocked off. The door of the safe was bulged in about one-eighth inch at the spindle. Several bolts on the door were loosened, but no cracks were visible. The nature of the explosive used prevented its being reduced in bulk so as just to cover the end of the spindle, and the tamping was not sufficient to direct a blow on the spindle necessary to drive it through and knock off the lock.

SIXTH EXPERIMENT.

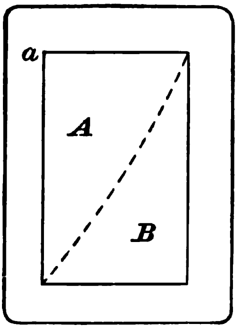
One ounce of explosive gelatine was packed in one-half the length of the crack between top of door and jamb from the left-hand side. This charge was pressed well back and down behind the step of first door plate and tamped with putty. Detonator held in cork plug was placed about the middle point of the charge.

As the result of this explosion the first two plates of the door were blown off bodily to a distance of 3 or 4 feet, being torn from the hinges. The jamb above and on left of door was badly racked and the plate so loosened that they could have easily been removed by a jimmy. Door plates were also loosened and could have been similarly removed, but it was decided not to resort to any mechanical means.

SEVENTH EXPERIMENT.

Two ounces of explosive gelatine were packed in crack between top of door and jamb from left-hand corner for a distance of about 4 inches and pushed well back and down behind the third step of door. The charge was tamped with putty and detonator in cork plug placed about the middle point of charge.

As the result of this explosion the third plate of door was one-half stripped off, as shown in the figure. That portion of the door marked A was raised, while the portion marked B remained firm. The corner *a* was lifted about 6 inches, and several bolts in the door plate were thrown out.



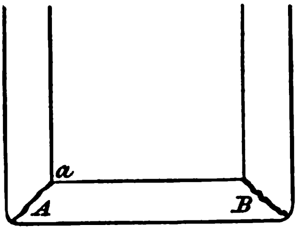
EIGHTH EXPERIMENT.

Eight ounces of Atlas powder, grade A, were packed behind the third plate already partially stripped off, sand was used as a tamp, and a detonator placed in the Atlas powder.

As the result of this explosion the third plate was entirely stripped off, the outside plate of door jamb on left of door was torn off, and the outside plate of jamb above the door was entirely removed. The inside plate of the jamb on the left side of door was blown in and all the plates of the door jamb above and on left of door were so loosened by the gases of explosion which had penetrated between them that the interior of the safe was disclosed to view.

NINTH EXPERIMENT.

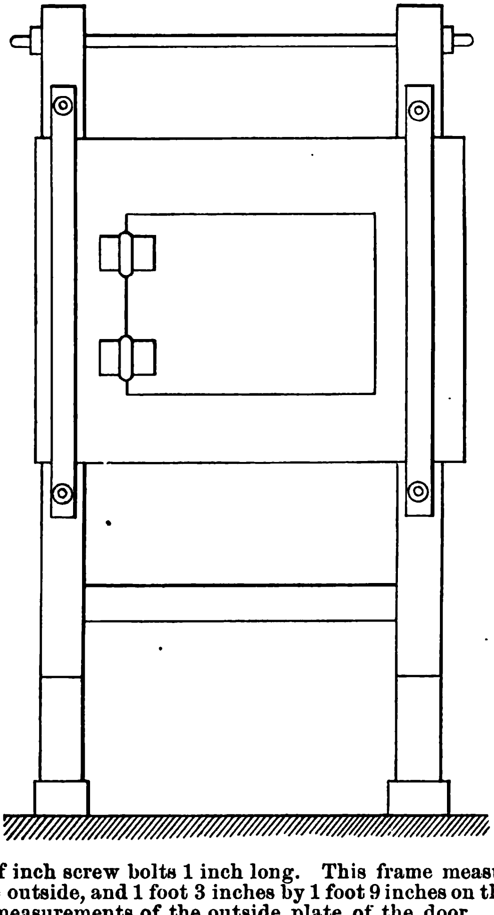
One and one-half ounces of explosive gelatine were packed in crack between fourth plate of door and jamb around the lower left-hand corner of the door. It occupied the distance of 1 inch up from lower corner on left side and a distance of 2 inches along crack below door from lower left-hand corner. This charge was pressed firmly in and up behind the fourth plate as far as possible; it was well tamped with putty and a detonator placed at angle (*b*). (See fig.)



After the explosion it was found that the outside plate of the jamb below the door was cracked at the corners at A and B. The fourth plate of door was bulged out about one-fourth inch at the corner *a*. The gases of explosion had penetrated between the jamb plates on the lower side of and below door, and had so loosened and separated them from each other that it was only necessary to remove the left and upper jamb plates with wedges and then pry the door over to the left. The bolts then became disengaged and the door fell out on the floor, revealing the whole interior of the safe. No further operations were necessary. The time of these experiments was not taken, but the entire work could be done with ease in two hours, and in a perfectly burglarious manner.

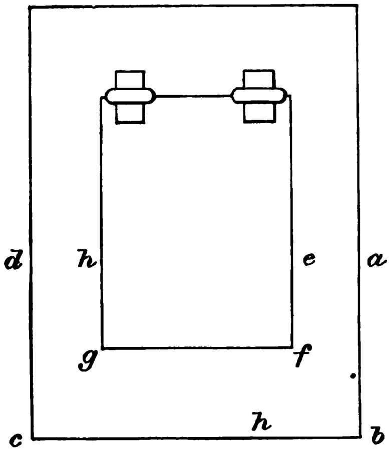
TENTH EXPERIMENT.

This experiment was conducted upon a section made to represent the front of a square safe with door, constructed as follows: It was made up of eight one-half inch wrought-iron plates, each plate being bolted to the one in front of it from behind with sixteen one-half inch screw bolts 1 inch long. This frame measured 2 feet 3 inches by 3 feet on the outside, and 1 foot 3 inches by 1 foot 9 inches on the inside, the latter being also the measurements of the outside plate of the door. The door was constructed of eight one-half inch wrought-iron plates. It was stepped off on the two narrow edges and was plane on the other two. The door swung on cast iron hinges. The whole section was securely fastened to a strong wooden frame. There were no bolts nor locks to the door, but across the back parallel to the shortest sides two heavy iron straps were secured. The whole section was very much stronger and better assembled than the ordinary square safe door of the same size and thickness. (See fig.)



In this experiment nitroglycerin was used as the explosive and the operation conducted as follows: The frame holding the door was canted over so that the section stood as shown below.

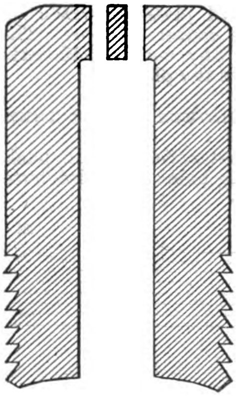
All around the outside of the door frame, from *a* to *b* to *c* to *d*, the cracks between the jamb plates were puttied. The cracks *e, f, g, h* around the door were also puttied front and back. At the point *e* a well of putty was made and some water poured into it. This ran in almost as rapidly as the well could be filled, showing that there was plenty of room in the cracks and crevices for a liquid explosive. At the end of about a minute a leak was observed on the under side of the door frame at *h*. The water was allowed to run out, the leak carefully stopped, and nitroglycerin poured into the well at *e*. It ran into the crack very quickly. In order to thoroughly appreciate how penetrating this liquid explosive is it must be borne in mind that although the plates of door and jamb were fitted together as closely as the screw bolts could hold them, and there could not have been one one-hundredth inch space between them, yet about two minutes after beginning to pour the nitroglycerin a leak was discovered between the two plates of the door frame at the point *h*. This was quickly stopped, and when two ounces of nitroglycerin had been poured in a detonator was placed against the crack between the door and door frame at the point *e* and firmly held in position by putty. Previous to placing the detonator a very thin strip of blotting paper soaked in nitroglycerin was placed in the crack at *e* to serve as an extra primer to assist in transmitting the detonation. Several 12 by 12 inch wooden beams were laid up against the section of the door and frame and the charge fired. The section was standing near the door of a small wooden building, and just inside, but no damage whatever resulted to it from the explosion. The effect of the explosion on the door and frame was as follows: One-half the wooden upright next the floor was broken off. The entire section was separated bodily from the wooden frame and thrown back 4 feet into the building. All the plates of the door frame below that part of the door where the nitroglycerin had been introduced were separated from each other by spaces varying from one-fourth inch to 1 inch, except the two front plates, which were thrown off bodily, showing very clearly that the nitroglycerin had penetrated between the second and third plates of the door frame. The first plate of the door frame on right of door was lifted out one-half its length at an angle of 45 degrees. The second plate was lifted out about one-half its length, the lower edge standing out 4 inches from the third plate. The lower third of the first plate of door was blown off. All the remaining plates of the door were separated from each other along their lower edges by spaces varying from one-fourth to three-fourths inch, the separation extending up about one-quarter the length of the plates. The inside plate of the door was dished in so as to bend the lower iron strap bolted to the back of door about one-half inch at center.



It appears from these results that the nitroglycerin was lodged principally between the plates of door frame below door, that the gases of explosion penetrated between the plates of door frame below and on right side of door, and between the plates of the door in the vicinity of the charge; that this operation of introducing nitroglycerin into the crack between door and door frame is a perfectly practical one, even where the fit is very close, and that a comparatively small quantity of nitroglycerin introduced in this manner will produce very quick and decisive results, against which no laminated structure can stand. The time required for this entire operation was less than one hour, and would not have been as long but for the fact that the cracks between the plates of door frame had to be carefully puttied, an operation not necessary when attacking a complete safe.

Another point must be considered in this experiment, viz, that the demolition in the case of a complete safe would have been more marked than in this instance of only a section, viz, door and frame, because in a complete safe there would be more rigid backing to the door and door frame to direct the energy of the explosive against them. In this experiment there was no backing whatever to the section; hence a certain amount of energy was expended in sending the door and door frame back a distance of 4 feet. The entire section weighed about 1,091 pounds.

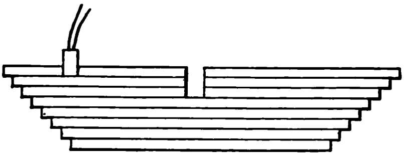
The following experiments, 11 to 19 inclusive, were made with a view of determining the practicability of entering the safe by removing each plate of the door successively. For this demonstration a section of one-half inch wrought iron plates, built to represent a safe door, was used. Its dimensions were the same as of that used in the tenth experiment, and it was constructed in precisely the same manner, but there was no frame around it. The section was laid horizontally on 12 by 12 wooden beams. A hole 1.1 inches in diameter was cut through the first plate, and threaded to receive a plug of the following description: (See Fig.)



It was made of iron, cylindrical, 2 inches high and 1.2 inches in diameter on plane part, and 1.1 inches on threaded part. A cylindrical hole four-tenths inch in diameter was cut through the axis of the plug to within one-quarter inch of the top, and beyond this two small holes one-tenth inch in diameter were cut through to the top of the plug. The bottom of the plug was dished out about one-eighth inch. It was made to hold a detonator against a charge of explosive placed in the hole through plate of door and pushed as far under plate as possible. Upon an examination it was found that the screw bolts held the first and second plates of the door so close together that it was not possible to push any solid explosive under the first plate, hence the following method was pursued:

ELEVENTH EXPERIMENT.

The plug was placed in the hole made to receive it and firmly screwed down against the second plate, the detonator having been placed within it, then it was turned back so as to raise it about one-sixteenth inch from the second plate, and

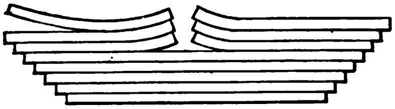


through the two small holes at the top of plug, out of which came the detonator wires, one-tenth ounce of nitroglycerine was poured. A half-inch iron plate was placed over the plug and over this about two bushels of sand in bags. The plug was screwed in at the point a.

As the result of this explosion about one-half of the first plate was lifted on the side in which the plug was screwed, the left edge of the first plate being raised 1 inch from the second plate. Eight bolts were stripped off, the first plate was then removed by wedges. The introglycerin used had undoubtedly run in under first plate. The cylindrical iron plug was blown out bodily and it made a hole through the half-inch iron plate that rested on it.

TWELFTH EXPERIMENT.

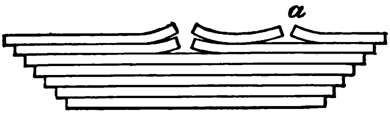
In the center of the door was a 1-inch hole extending through three plates of the door. Into this hole were poured one-fourth of an ounce of nitroglycerin, a detonator was placed in the charge, the hole covered with putty and two sand bags placed over all.



As the result of this explosion the second and third plates were separated one-fourth of an inch, and the third plate separated one-fourth of an inch from the fourth around the hole in the center of door. The nitroglycerin evidently had not run between the plates to any considerable extent, but the gases of explosion had penetrated so as to separate the plates.

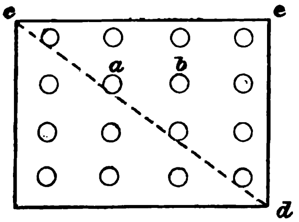
THIRTEENTH EXPERIMENT.

Thirty grains of forcite powder, No. 1, were packed between second and third plates of door, through the plug hole at *a*, a detonator was placed in the plug-hole *a*, and all covered compactly with putty. Around the edges where the second plate was separated from the third, the cracks were also filled with putty. The result of the explosion was to lift the second plate a little more around the plug-hole *a*, but owing to the small quantity of explosive used and the relatively large space already existing between the second and third plates, most of the gases of explosion blew out between them.



FOURTEENTH EXPERIMENT.

It was noticed that when the conical-headed screw bolts were sheared off the heads were left loose, and a considerable space was found between them and the plate into which they were counter-sunk from beneath, thus giving an excellent opportunity for the introduction of a liquid explosive. A small well of putty was built around two bolt holes, *a* and *b*, and one-tenth ounce of nitroglycerin was poured in at each hole. A small strip of nitroglycerin-soaked blotting paper was inserted at *b*. The detonator placed against it and held firmly with putty. Putty was also placed over *a*.

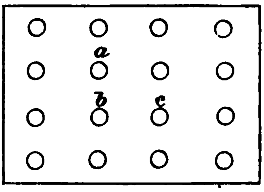


As a result of this explosion, the half of the second plate marked *c*, *e*, *d*, was lifted and bent over the line *c*, *d*, the corner *e* standing out from the third plate about 4 inches. The second plate was then removed with wedges in a few minutes.

FIFTEENTH EXPERIMENT.

Wells of putty were built around the bolt-holes *a*, *b*, and *c* and one-twelfth ounce of nitroglycerine poured in at each plate.

A strip of nitroglycerin-soaked blotting paper was inserted at *b*, a detonator placed against it and firmly held by putty; *a* and *c* were also covered with putty. An iron plate was placed over all, and two sand bags with 1 bushel of sand in each were placed on top of this.

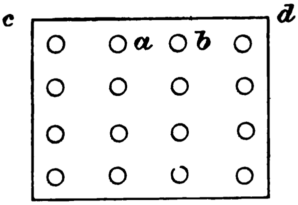


As a result of this explosion, the third plate was lifted bodily from the fourth to no greater distance than 1 foot.

SIXTEENTH EXPERIMENT.

The remainder of the door was now set upon edge as shown in the figure, and backed by two heavy 12-inch timbers laid perpendicular to the plane of the door-plates.

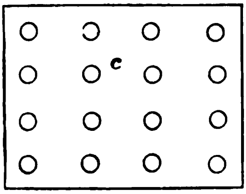
Two wells of putty were built at *a* and *b* and one-tenth ounce of nitroglycerin poured into each. A small strip of nitroglycerin-soaked blotting paper inserted at *b*, a detonator placed against it and firmly held by putty; *a* was also covered with putty.



As the result of this explosion the fourth plate was separated from the fifth along the edge *c d*, about one-fourth inch, and the two upper horizontal lines of bolts were sheared off, but the two lower ones still held.

SEVENTEENTH EXPERIMENT.

In the space between the fourth and fifth plates were placed two sheets of blotting paper, each 4 by 8 inches. They occupied the middle portion of the space. On these were poured one-fourth ounce of nitroglycerin.

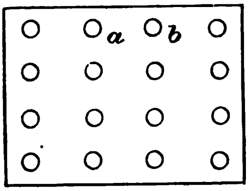


In this space around the bolthead at *c* a small strip of nitroglycerin-soaked blotting paper was placed. A detonator was laid against it and firmly held by putty. No other tamping was used.

As the result of this explosion the fourth plate was thrown off bodily about 30 feet to the front. This experiment is particularly interesting as showing the effectiveness of concentrating a charge of nitroglycerin, by simply holding it in any fixed location through the medium of blotting paper or some other equally absorbent material.

EIGHTEENTH EXPERIMENT.

Wells of putty were built around the bolt holes *a* and *b*. One-quarter ounce of nitroglycerin was poured around the boltheads. A small strip of nitroglycerin-soaked blotting paper was inserted at *b*; a detonator was placed against it and firmly held with putty; *a* was also covered with putty.

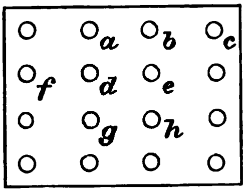


As the result of this explosion the fifth plate was blown off bodily about 30 feet to the front.

NINETEENTH EXPERIMENT.

The same operation was conducted on the next plate, the sixth, but the charge of nitroglycerin was reduced to one-eighth ounce—one-half the amount used in the preceding experiment.

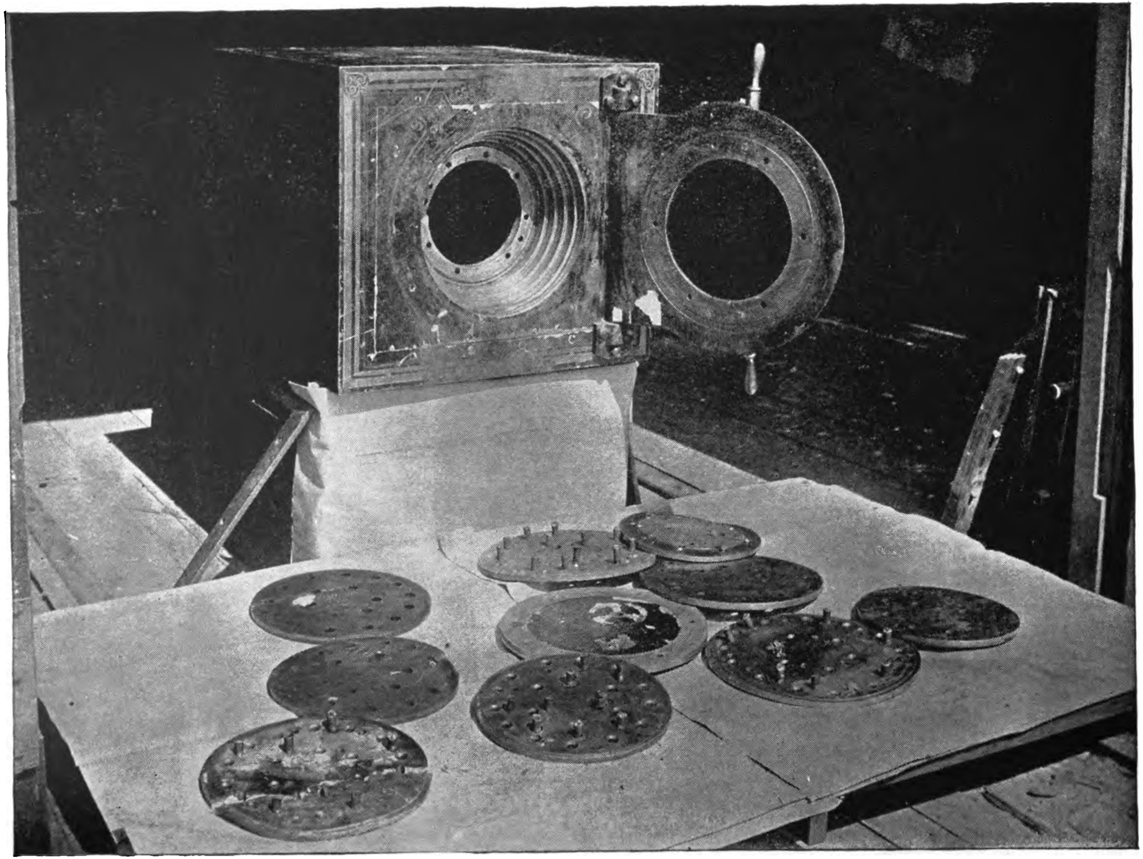
As the result of this explosion the sixth plate was bulged out around the center about 1 inch and the bolts *a, b, c, d, e, f, g, h,* or eight of sixteen, were stripped off. A very pretty demonstration, that one-half the quantity of nitroglycerin necessary to entirely remove the plate had been used.



In this series of experiments (11 to 19 inclusive) on the section representing a laminated door, the actual time of each was as follows:

	Minutes.
Eleventh	15
Twelfth	6
Thirteenth	5
Fourteenth	12
Fifteenth	5
Sixteenth	5
Seventeenth	6
Eighteenth	6
Nineteenth	6

making a total of one hour and six minutes, and there remained only three half-inch plates to remove. It will be observed that for this size of door plate, 21 by 15 inches by one-half inch thick, one-quarter ounce of nitroglycerin introduced so as to run behind the plate is about the required amount necessary to remove it bodily, provided the plate in question is not separated too much from the one behind it. In such a case there is a vent for the gases of explosion. When a plate is thrown off bodily the force exerted on the bolts that are sheared appears to be enough to separate the next plate from underneath it just a sufficient distance to allow the introduction of a similar charge of nitroglycerin, which at the next firing removes the plate bodily, and so on through the entire operation. With a sufficiency of tamping the noise of explosion can be so deadened that I am of the opinion that the entire operation could be conducted in a bank vault without attracting any practical attention.



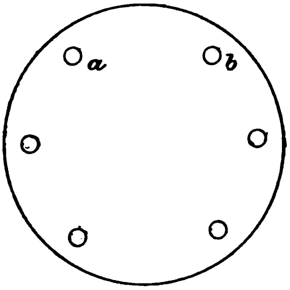
Screw Door Safe. View showing Safe and Plates after the Operation.

TWENTIETH EXPERIMENT.

The safe used in this experiment was made by M. Briggs & Co., Rochester, N. Y. and furnished with a screw door.

It measured 2 feet 9 inches on the outside. The body of the safe was built up of alternate iron and steel plates approximately one-half inch thick, and the back measured 4½ inches through. The door was composed of ten one-half inch plates arranged as follows: First and second, iron; third, steel; fourth, iron; fifth, steel; sixth, iron; seventh, steel; eighth, iron; ninth, steel; tenth, iron. The door had five steps; the diameter of the first and second plates was 15 inches, and of the ninth and tenth, 12 inches, there being two plates to each step. The plates were fastened together from the inside with screw bolts, the steel plates being held on the shank of the bolts, which passed through them, and were screwed into the iron plates. An annular iron ring 1¼ inches thick and 2 inches wide was fastened to the inside plate from the inside with ten bolts, and had a screw thread cut on its exterior circumference. This screwed into another annular ring fastened to the inside plate of safe around the door opening. A circular iron frame hung on hinges acted as a carrier to the door and into this was screwed an annular iron ring through which, and into the door, eight one-half inch screw bolts passed. When these bolts were removed, the circular iron frame with annular ring could be swung back and the screw door presented itself with its first plate flush with the outside of the safe, and showing six one-half inch bolt holes through the first plate of the door, arranged in a circle about 1 inch from outside circumference. Two handles diametrically opposite were attached to the annular ring screwed into the iron frame hinged on front of safe, and were used to screw up and unscrew the door. Before commencing this experiment, the door was screwed in and locked, and the hinged iron frame with annular ring unbolted and swung back out of the way. (See photograph.)

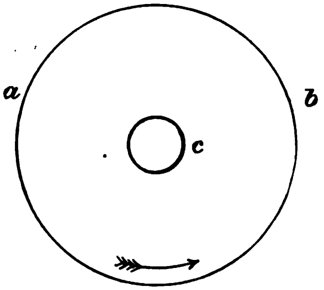
The object of this experiment was to determine the practicability of obtaining entrance into the safe through the door, by removing plate after plate, and to ascertain the time necessary to gain such entrance. The first operation was to introduce about one one-hundreth ounce of nitroglycerin into the two bolt holes *a* and *b* through the first plate, place a detonator in each hole, tamp with putty and fire. This detonation, although producing the smallest possible noise, caused the first plate to spring away from the second, so that a subsequent charge of nitroglycerin could be poured in between them.



In each operation where explosive was used, one-quarter ounce of nitroglycerin was poured into wells of putty made around two bolt holes similarly situated to *a* and *b* in the figure. The explosive in each case ran in rapidly behind the plate, a detonator was placed against one of the holes, both were then tamped with putty and the charge fired. The operation commenced at 3:45 p. m., September 16, 1891. At 4:05 p. m., the first plate of iron was blown off bodily a distance of 50 feet; 4:15 p. m., the second plate was blown off bodily about the same distance; 4:20 p. m., the third plate was blown off bodily, about the same distance, and the fourth plate right after it struck about 30 feet to the front. The fifth plate was found loosened and simply hanging on the bolts. It was taken off at 4:21 p. m. At 4:26 p. m., the sixth plate was blown off a distance of 50 feet. At 4:30 p. m., the seventh plate was blown off a distance of about 50 feet, and, with it, the eighth and ninth plates were thrown out about 30 and 20 feet, respectively. The tenth plate was knocked in with a jimmy in two and one-half minutes, so that the actual time of the operation was thirty-eight and one-half minutes. Before forcing in the tenth plate as described, two experiments were made in order to ascertain if this plate could be torn out by explosive force. First: the space around the tenth plate was puttied from *a* to *b* in direction of the arrowhead.

A well of putty was made at *b* and one-fourth ounce of nitroglycerin was poured in. A detonator was then placed at *b*.

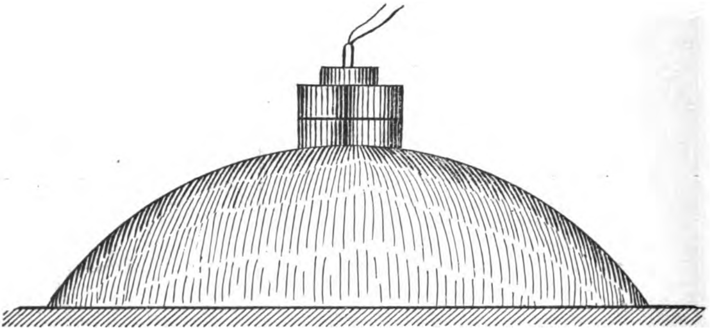
The result of this explosion was nothing practical. The nitroglycerin did not run between the plate and the annular ring which was bolted to it, and consequently the gases of explosion blew out around the plate. Second: A thin glass phial was filled with 1 ounce of nitroglycerin, a detonator placed in it, and the charge passed in through the spindle hole *c* in the center of plate and suspended close behind the plate below this hole.



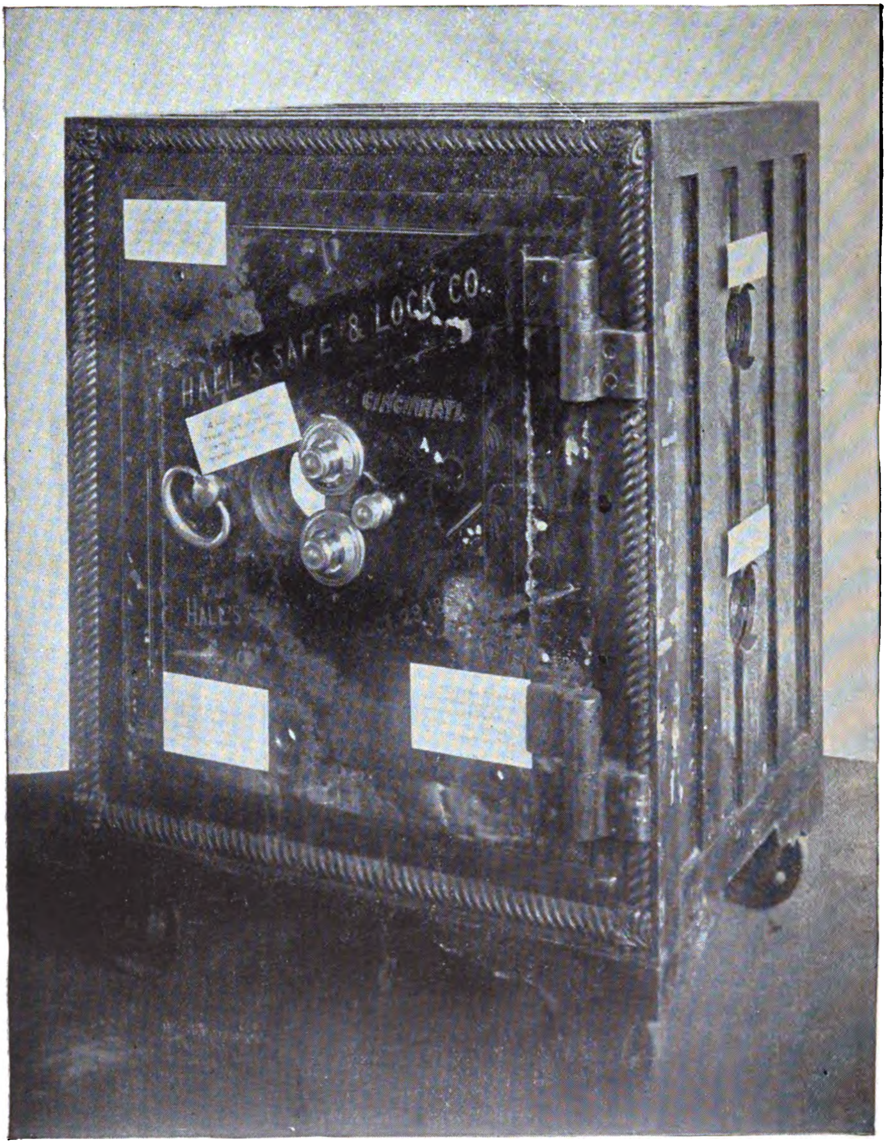
The result of the detonation of the nitroglycerin was that the plate was bulged out at the center about one-half inch, but was not blown off. This was owing to the fact that the charge of nitroglycerin was not large enough, as the gases of explosion had about 8 cubic feet of space inside the safe in which to expand, and there were many vents in the shape of bolt holes in the plate varying from one-half inch to three-fourths inch through which the air and gases could escape. The results obtained from this experiment lead to the conclusion that it is perfectly practical to open a screw-door safe tearing off plate after plate of the door; that the circular form of plate is a peculiarly good one for the success of the operation, and that the entrance desired can be effected in a very short space of time. In regard to the noise, it is certain that with a proper tamping of sand bags or other materials this could be deadened so as not to attract any practical attention, and the entire operation is, in my opinion, a perfectly burglarious one.

TWENTY-FIRST EXPERIMENT.

A section representing the back of a 32-inch Corliss safe is shown in the figure.



This back was placed firmly in the sand, which was also packed well up in the interior in order to present as highly resisting a medium under it as possible. On top of this, as shown in the figure, were placed four disks of wet and one-half a disk of dry gun cotton, in which was placed the detonator. The detonation of this mass of gun cotton, weighing 4 pounds and 6 ounces, produced no result whatever except to show up a very fine hair crack, not over one-eighth inch deep and 8 inches long. This experiment demonstrates very conclusively that the Corliss safe is proof against that mob violence which would be directed towards cracking the safe open by means of a large mass of explosive detonated on its outside.

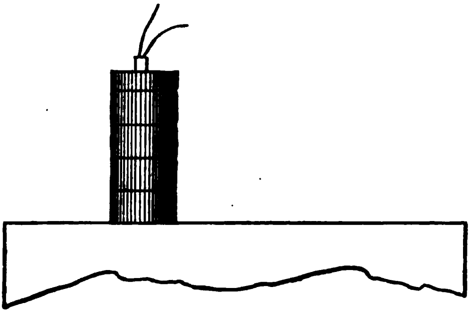


Hall Safe. Having been Previously Operated upon by Cutting Several 4-inch Holes through the Body and by Drilling through Several of the Threaded Conical Bolts.

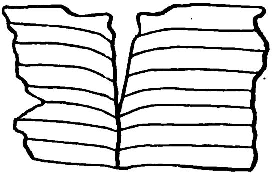
TWENTY-SECOND EXPERIMENT.

This experiment was conducted on the door of a safe made by the Hall Safe and Lock Company. It was laid upon its back on timbers. The door was closed and locked. The safe is shown in the photograph. It measures 2 feet 11 inches high, by 2 feet 8 inches wide, by 2 feet 1 inch deep. The sides, top, bottom, back and door are 3 inches thick and are built up of alternate iron and steel plates to the number of eight. The object of this experiment was to demonstrate the effect of mob violence in an attempt to break in the door of a square safe with explosives. On the door of this safe, about halfway between the center and lower edge, were placed 4 discs of wet surmounted by one-half a disk of dry gun cotton containing the primer. The arrangement is shown in the figure, and the weight of the charge used was 4 pounds 6 ounces. There was no tamping.

As a result of this explosion, a circular indentation three-fourths inch in diameter and one-fourth inch deep was made in the first plate of the door where the gun cotton stood, and was an imprint of the cake. These cakes are 3½ inches in diameter, and through their center passes a one-fourth inch hole for the detonator. In the center of the imprint made by the explosion was a hole 1 inch in diameter, extending through the first two plates and part of the third, which was literally fused out by the gases of explosion, rushing into the quarter-inch hole through the pile of gun-cotton cakes, while beyond the third plate, right through the safe door, the ballistic effect of the gases was shown by the bulging in and cracking of the five remaining plates, the inside one being indented about one-eight inch and cracked through. The figure below, giving a section through the axis of the charge of gun cotton, will serve to show the effect produced by this explosion.



Before Explosion.



AFTER EXPLOSION.

Beyond the second plate the appearance was as if a comparatively sharp tool had been driven through the remaining plates. The explosion of another charge at the same point would have undoubtedly driven a hole of considerable size right through the safe door.

TWENTY-THIRD EXPERIMENT.

In this experiment ten cartridges (5 pounds) of forcite powder No. 1 were piled up on back of Corliss safe on the same spot where the gun cotton had been placed. (This was the same back that was used in the gun cotton experiment No. 21.)

The figure will show the general arrangement of the cartridges with the detonator placed in the middle of the top stick. No tamping was used and only a small quantity of sand was pressed around the bottom layer of cartridges to hold them firmly in position.

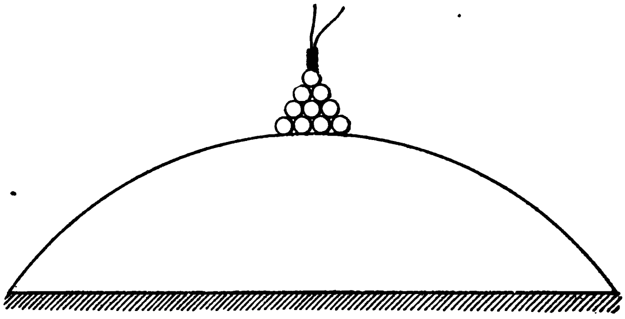
The result of this explosion was that the crack developed in the gun cotton experiment, No. 21, was lengthened about 4 or 5 inches, but neither widened nor deepened.

A small chip of iron about 1 inch in diameter and one-fourth inch thick was removed from the surface of the back near the charge.

TWENTY-FOURTH EXPERIMENT

Ten cartridges (5 pounds) of forcite powder No. 1 were placed on the door of the same Hall safe as was used in experiment No. 22, the safe lying on its back as in that experiment. The forcite was piled exactly as in the twenty-third experiment, and was placed at a point about halfway between the center and the upper edge of the door. The detonator was imbedded in the top cartridge of the pile. No tamping was used.

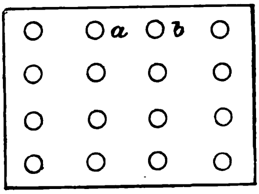
The result of this explosion was to dish the door in around the point where the charge had been placed three-eighths-inch at its deepest part. The door was not forced in by the explosion and no cracks were developed in the outside plate.



TWENTY-FIFTH EXPERIMENT.

This experiment was conducted on a wrought-iron door built up exactly as the one used in experiments eleven to nineteen inclusive, and it was of the same dimensions throughout. The object aimed at was to determine the minimum quantity of nitroglycerin necessary to tear off bodily the individual plates of this door, and to ascertain the time necessary to go through the door. It was placed in a vertical position standing on its long edge, its back resting against heavy timbers, which themselves were supported by a solid earthen embankment. The preliminary operation of starting the first plate slightly away from the second was begun at 10:25 a. m., October 2, 1891, and consisted in pouring about one-fiftieth ounce of nitroglycerin into a central 1-inch hole, which extend through three plates of the door, (see twelfth experiment), placing a detonator in the hole, tamping with putty and firing

As the result of this explosion the first plate was started out about one-thirty-second inch. A well of putty was then placed around the same central hole, and a half ounce of nitroglycerin poured in between the first and second plates. A detonator was placed against the space between the first and second plates in this hole, tamped with putty, and at 10:30 a. m. the first plate was blown off bodily a distance of 40 or 50 feet. From this time on until the completion of the experiment the nitroglycerin was poured in behind each successive plate through the space between the bolt heads and plates at *a* and *b* shown in the figure.



The detonator was placed at the right-hand hole and at each instance *a* and *b* were tamped with putty before firing. One-fourth ounce of nitroglycerin was poured in behind second plate, and at 10:37½ a. m. it was blown off 30 or 40 feet. Three-sixteenths ounce of nitroglycerin was then poured in behind third plate, and at 10:31½ a. m. it was blown off 20 or 30 feet. One-eighth ounce of nitroglycerin was then poured in behind the fourth plate, and at 10:45 a. m. it was-one half lifted, the upper eight bolts being broken, the lower eight still holding, and the upper half of the plate was bent out at an angle of about 15°. The lower half of the space between fourth and fifth plates was now filled with sand and over this one-fourth ounce of nitroglycerin was poured so that it was located about the center of the plates. The detonator was embedded in this sand dynamite. A sand tamping was placed over all and well packed.

As the result of this explosion the fourth plate was thrown off a distance of over 60 feet at 10.48 a. m. One-third ounce of nitroglycerin was poured in behind the fifth plate, and at 10.53 a. m. it was blown off about 40 feet. One-third ounce of nitroglycerin was poured in behind the sixth plate, and at 10.57 a. m. it was blown off about 40 feet. One-third ounce of nitroglycerin was poured in behind the seventh plate, and at 11 a. m. it was blown off about 40 feet. The eighth plate alone remained, considerably dished in about the center. The total time of this operation was thirty-five minutes. To this must be added the time necessary to force in the eighth plate by a jimmy or other contrivance—an operation which at this stage would certainly not require more than two minutes. The quantity of nitroglycerin necessary for each successful operation when blowing off plates of this size is from one-fourth to one-third ounce. The distance between the plates where the nitroglycerin was poured in was about one-thirty-second inch, and in some cases less, but not more. With proper tamping the noise of explosion can undoubtedly be reduced to such an extent as to render the operation practically burglarious.

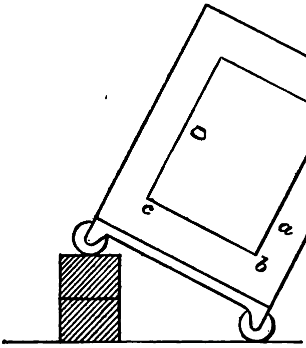
TWENTY-SIXTH EXPERIMENT

A cartridge of forcite powder No. 1, weight 10 pounds, was made up as follows: Seven sticks of this powder were tied together in a cylindrical form and firmly held by a wrapping of wire. Seven more sticks were tied together in the same way. Six more sticks were then tied together in a similar manner. The first bundle was stood on end, on this the second bundle was placed, also on end, and on the top of this the third bundle, also on end. Around this cylindrical mass a piece of tar paper was tightly wrapped and secured in place by wire. Another ten-pound cartridge of forcite powder No. 1 was made up exactly like the first. One of these cartridges was placed on the same back of Corliss safe that was used in the twenty-first and twenty-third experiments and upon the same spot. The other cartridge was placed on the door of the same Hall safe that was used in the twenty-second and twenty-fourth experiments, and on the same spot where the forcite cartridge was placed in the twenty-fourth experiment. A detonator was placed in the top of the center stick of forcite powder, in the upper bundle of each cartridge. These detonators were connected in series and fired simultaneously. The result on the Corliss back was that the crack developed in the previous explosions was extended 3 or 4 inches, but not appreciably widened nor deepened, as far as could be ascertained.

The result on the door of the Hall safe was that the depression made by the explosive used in the twenty-fourth experiment was increased 1⅛ inches, making a total depression for the two charges of 1½ inches. No cracks were developed in the outer plate, nor in any of the underlying wrought-iron plates, but the intervening steel-plates were severely shattered and broken up. No tamping was used for either of these two cartridges.

TWENTY-SEVENTH EXPERIMENT.

The Hall safe used in experiments 22, 24, and 26 was raised to its proper position and then canted as shown in the figure.

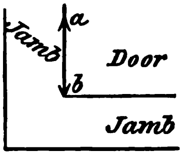


The lower portion of the crack above the door from *a* to *c* was carefully puttied, and a well of putty made at *a*. Into this were poured 3.2 ounces of nitroglycerin, which rapidly ran into the space between the door and jamb. A detonator was placed at the point *a* and well covered up with putty. Several heavy beams were placed in front of the door to arrest flying pieces.

The result of the explosion was decidedly disastrous to the safe, and its inside was exposed to view. The front, right side, and bottom were torn out from the lower corner and the door could easily have been pried open in a very few minutes. The steel plates, some of which had been shattered by the previous explosions on the door, and more thoroughly by this, fell down in a pile of small fragments under the lower corner. The accompanying photographs will show the effect produced by the explosion. This experiment did not occupy more than fifteen minutes, and is a practical burglarious operation which can be conducted upon laminated safes.

TWENTY-EIGHTH EXPERIMENT.

This experiment was conducted on the Valentine & Butler safe shown in the accompanying photograph, and was made with a view of determining the practicability of introducing nitroglycerin-soaked blotting paper in small quantities between the door and jamb, and, exploding the safe, to ascertain whether the corner of a plate could be so raised as to enable a wedge to be inserted under it and the plate pried off. Thus by a series of light explosions it would be possible to gain access to the safe's interior. First, a strip of ordinary blotting paper 5 inches long and three-fourths inch wide was soaked in nitroglycerin and slipped into the lower portion of the crack between the door and jamb, and on the left side of the door. It occupied the position *a b* in the figure.



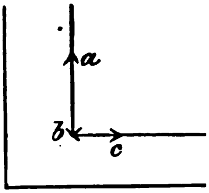
This was covered with putty and a detonator placed at *b*.

As the result of this explosion the first plate of the door was lifted out from the lower left-hand corner at *b* a distance of 5 inches, and separated from the second plate along the vertical edge a distance of 1 foot up from *b* and along the horizontal edge a distance of 9 inches from *b*. Second, two strips of nitroglycerin-soaked blotting paper, each 5 inches long and three-fourths inch wide, were placed in the crack between the second plate of door and jamb, occupying the position *a b* as in the preceding figure. It was covered with putty and a detonator placed at *b*.

As the result of this explosion the second plate of the door was lifted out at the lower left-hand corner and closed up against the first plate just operated upon. The explosions in each case were light, and the result justifies the conclusion that it is perfectly practical to successively lift out the corners of plates by a series of light explosions and to remove each plate with wedges until the interior of the safe is reached.

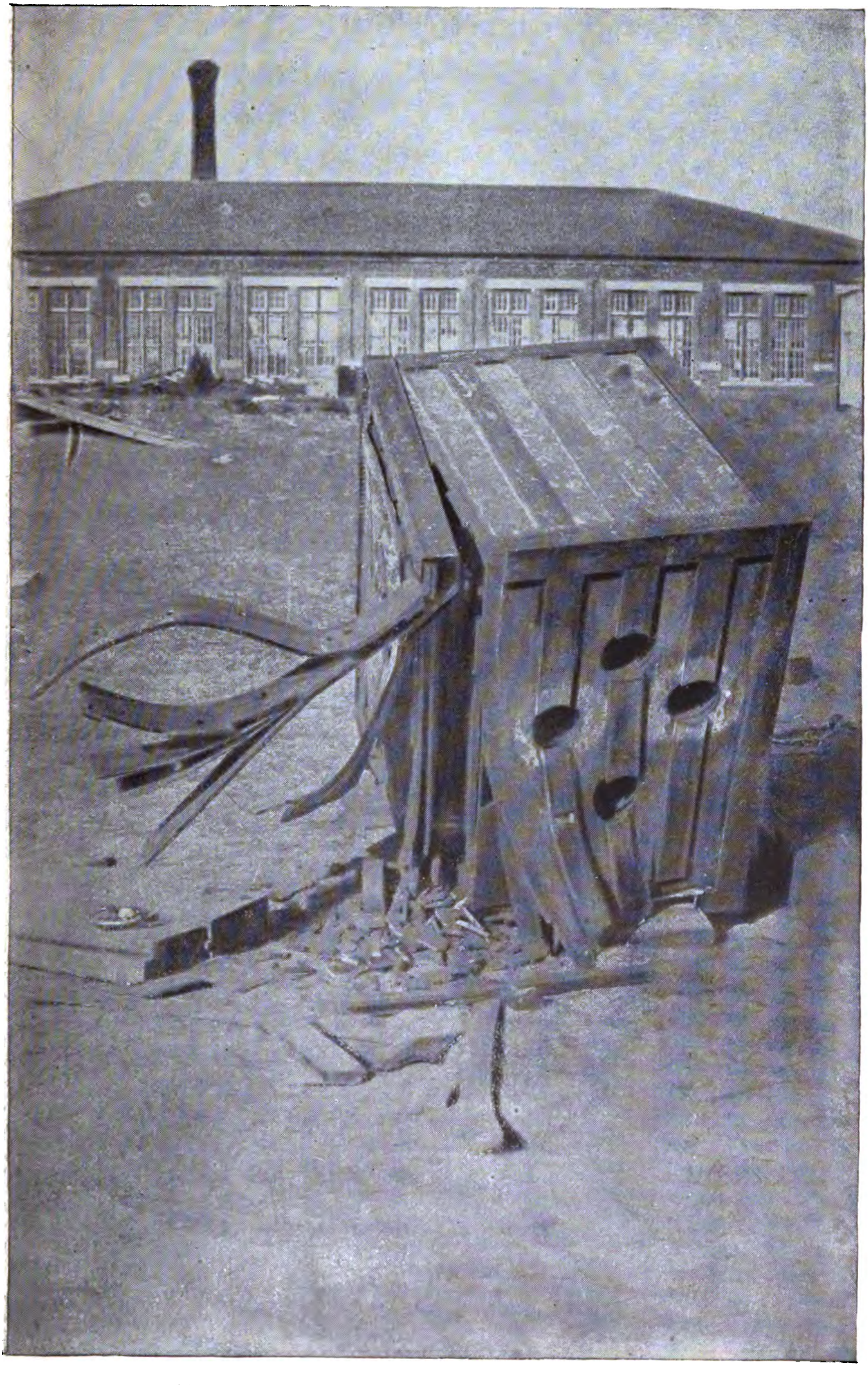
TWENTY-NINTH EXPERIMENT.

This was a continuation of the above experiment and at the same point of door and on the same safe. First, a strip of blotting paper was soaked in nitroglycerin and inserted in the crack *a b* between the third plate of the door and jamb.

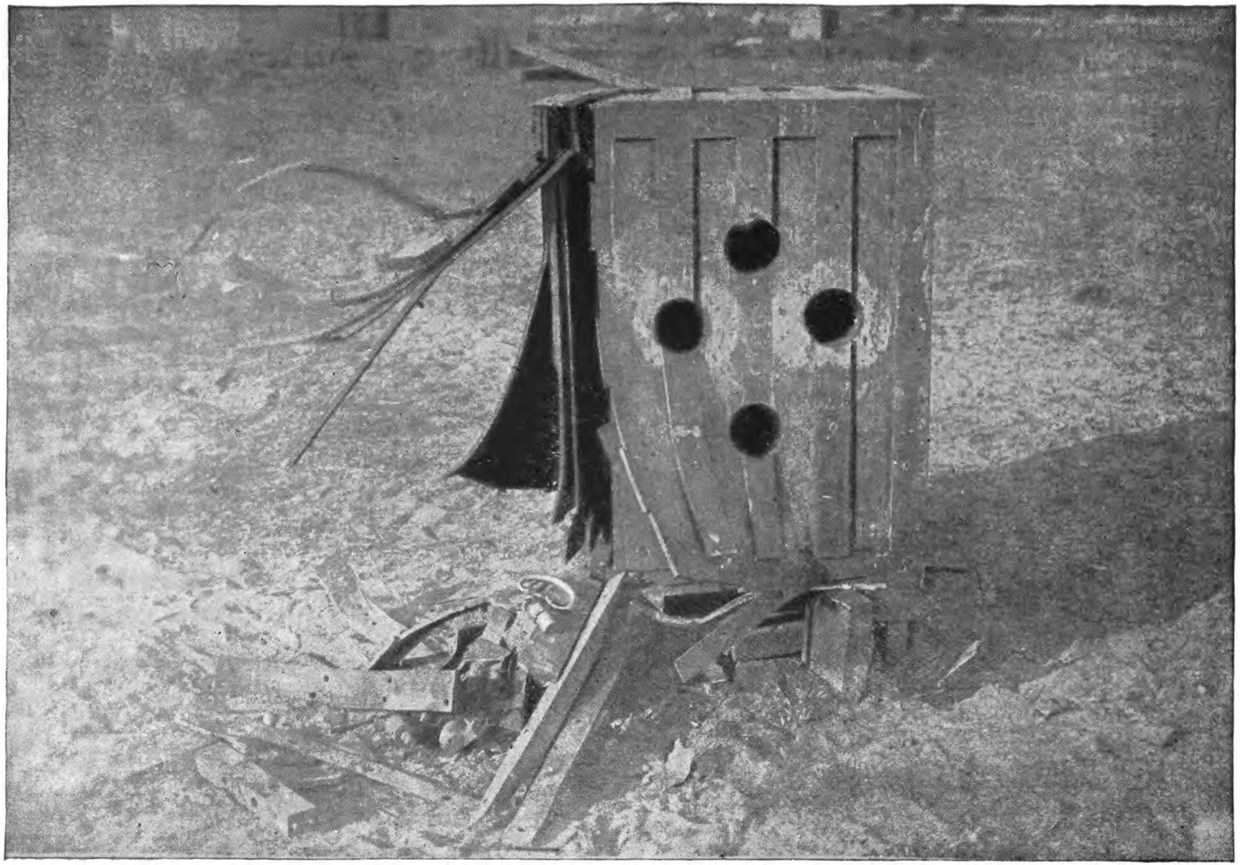


This strip was 5 inches long and three-quarters inch wide. A second strip of nitroglycerin-soaked blotting paper was inserted in the crack *b c* between the third plate of door and jamb. This strip measured 2 inches long and three-quarters inch wide. The crack *a b c* holding the blotting paper was covered with putty and a detonator placed at *b*.

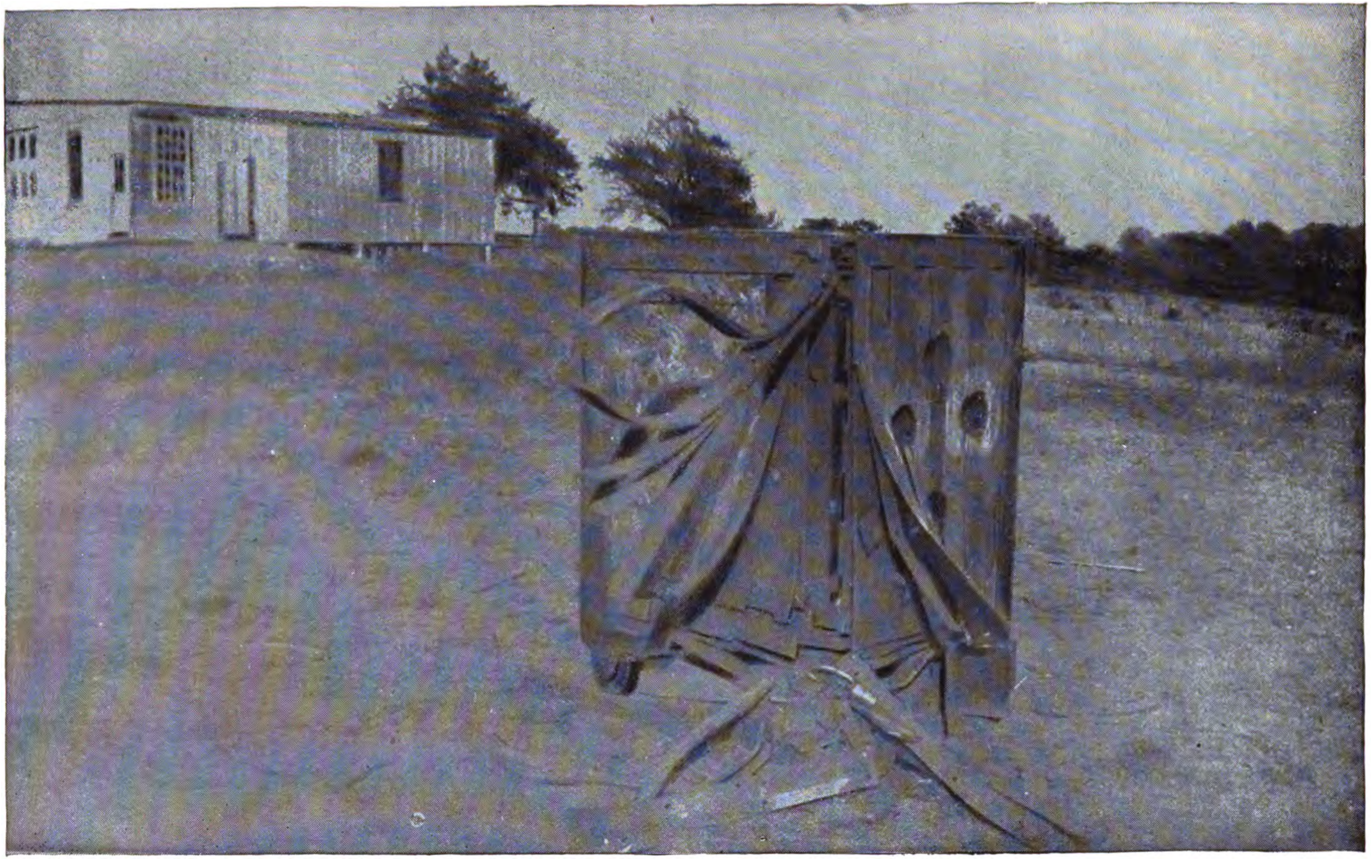
As the result of this explosion the third plate of the door was lifted out at the lower left-hand corner close up against the second plate previously operated upon.



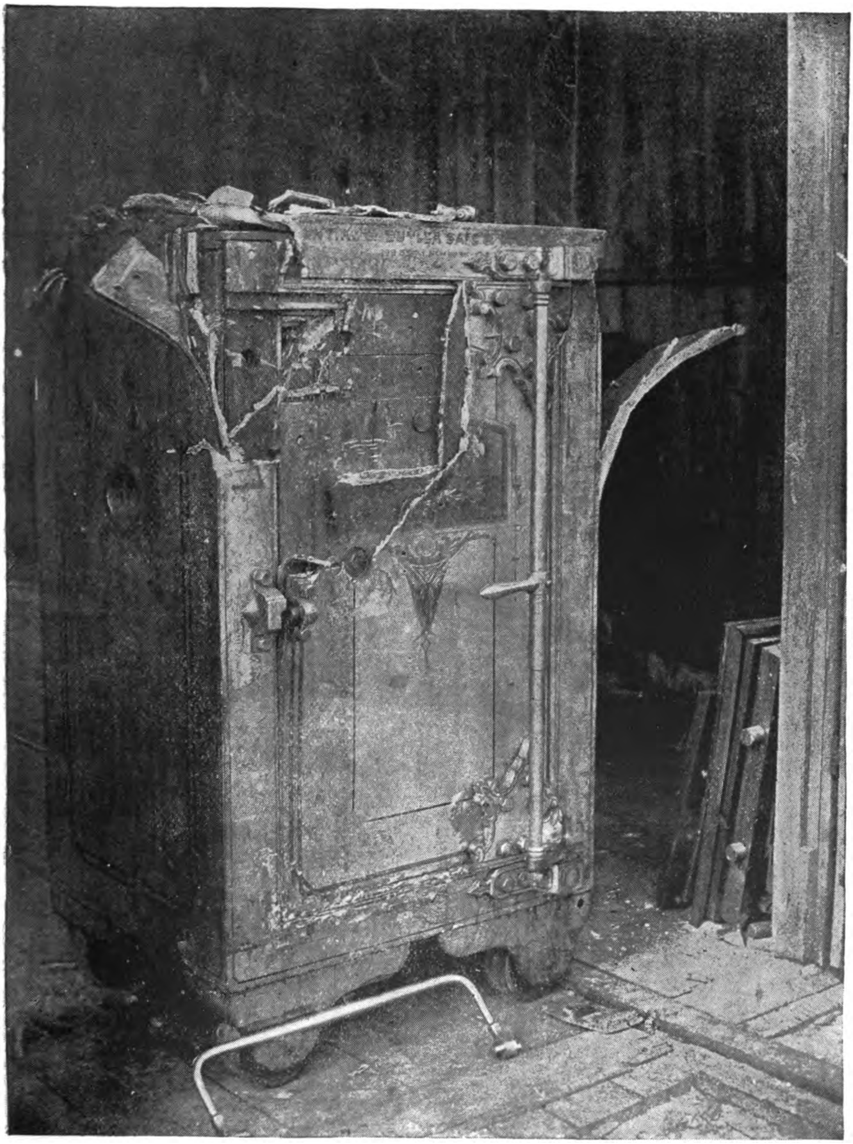
Hall Safe. View immediately after the Explosion.



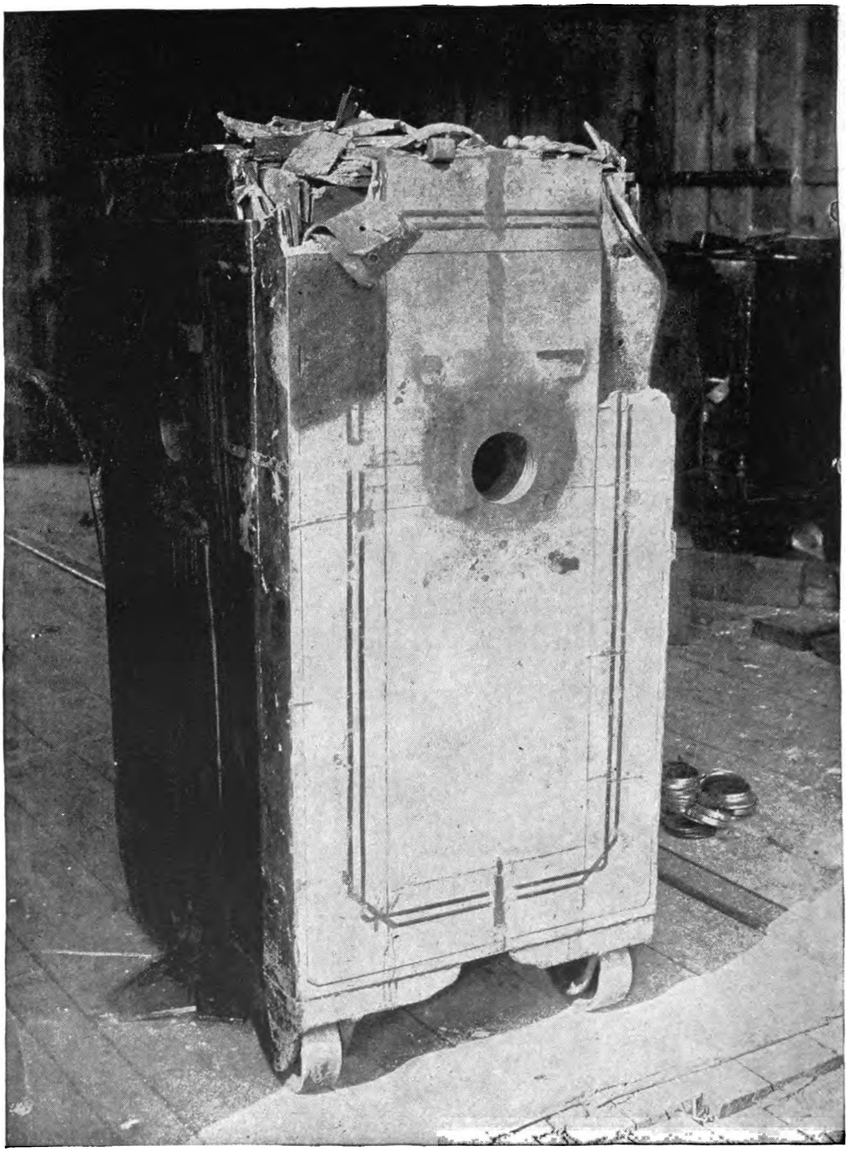
Hall Safe. View after the Explosion.



Hall Safe. View after the Explosion.



VALENTINE & BUTLER SAFE. PREVIOUSLY OPERATED UPON BY CUTTING A 4-INCH HOLE THROUGH THE BODY AND BY TEARING OPEN THE CORNERS WITH WEDGES.



VALENTINE & BUTLER SAFE. SIDE VIEW OF SAFE SHOWN IN PRECEDING PHOTOGRAPH.

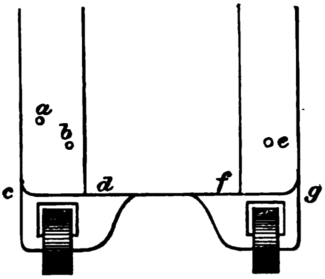
Second, it was now found as the interior of the safe was approached that the cracks between the plates of the door and door jamb became much wider, and therefore a new expedient was resorted to, viz: a quantity of cotton waste was soaked in nitroglycerin and pressed into the crack *a b* for the length of about 4 inches. It was then covered with putty, a detonator placed at *b*, and fired.

As the result of this explosion the fourth plate of the door was lifted out 1 inch at the lower left-hand corner *b*. The operation could easily have been continued, and, in a perfectly burglarious manner, access could have been had to the interior of the safe in a few hours. There is no reason why this remark should not apply to any laminated construction extant.

THIRTIETH EXPERIMENT.

On the left side of the Valentine & Butler safe shown in the photograph, and at the point *a* (see accompanying figure), about 4 inches from the bottom of the safe, a one-eighth-inch hole was drilled through the first plate.

This portion of the first plate was in the form of a wrought-iron strip about 9 inches wide and three-fourths inch thick, extending around the safe, and having solid angle corners. A well of putty was placed around *a*, and into it was poured a teaspoonful of nitroglycerin. This ran in very slowly, owing to the fact that it was appreciably thickened by being brought into contact with the very cold iron of the safe. It disappeared in about three minutes. A small strip of nitroglycerin soaked blotting paper was now placed in the hole *a* and pushed back to the second plate. Against this a detonator was placed and firmly held in position with putty. When fired it did not detonate the nitroglycerin. Another well of putty was made at *a* and two more teaspoonfuls of nitroglycerin were poured into it. A strip of blotting paper was prepared as before and inserted at *a*, and a detonator placed and held in position by putty as in the previous case. When fired this did not detonate the nitroglycerin. Another one-eighth-inch hole was now very carefully bored through the first plate at *b*; into this were poured about ten drops of nitroglycerin. A small strip of blotting paper and detonator were placed as before. The nitroglycerin was detonated; the left wheel shown in the figure and the first two plates on the bottom of the safe were blown off; the strip behind which the nitroglycerin had been poured was torn out along the line *c d*, and the strip was lifted from the next plate about 3 inches at *c d*, and separated from it for a distance of about 6 inches up from *c d*. It was intended to use only a teaspoonful of nitroglycerin in this experiment, in order to determine whether so small an amount would tear out the angle iron at the corner, and thus open the way for subsequent operations with wedges, etc.



The greater effect produced on the bottom plates of this safe shows that the nitroglycerin had run down and back over these plates, and hence was not confined at the point where its effect was particularly desired.

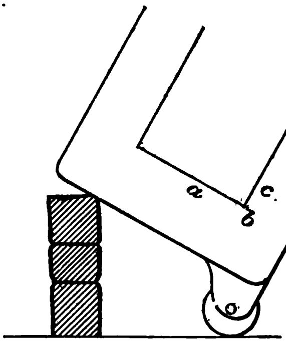
THIRTY-FIRST EXPERIMENT.

This experiment, similar to the preceding, was made on the other strip (see figure at the beginning of thirtieth experiment), and a one-eighth-inch hole was bored through the first plate at *e*, a well of putty built around it, and 2 teaspoonfuls of nitroglycerin were poured in. A strip of nitroglycerin-soaked blotting paper and detonator were placed as in the preceding experiment. This detonator and two more subsequently used at *e* failed to explode the nitroglycerin. It was then noticed that some of the nitroglycerin was leaking out at the bottom of the safe near the right wheel in the figure, so the detonator was placed at this point and fired. The nitroglycerin exploded, the right wheel was shattered, and the strip behind which the nitroglycerin had been poured was bulged out about one-fourth inch near the solid angle *f g*, but not cracked. From the several failures to detonate the charge through the one-eighth-inch hole it seemed probable that such a small orifice may prevent the transmission of the detonation to the charge behind, and, especsally so, if a space between the plates is sufficiently large to allow the glycerin to run away.

In these experiments account must be taken of the fact that the plates of this safe were very cold, and it is highly probable that this also prevented the transmission of the detonation in the instances mentioned. To overcome this difficulty it is only necessary to warm the plates. Such a plan was resorted to in a succeeding experiment, No. 41.

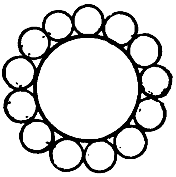
THIRTY-SECOND EXPERIMENT.

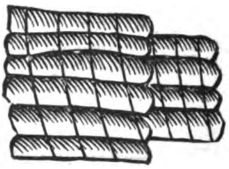
The same safe, Valentine & Butler's, was canted over as shown in the figure, and the lower hinge removed from the door. Putty was placed over the space between the door and the jamb, from *a* to *b* to *c*. A well of putty was made at and 2 ounces of nitroglycerin poured into the crack of the door at this point. It ran in very rapidly, and a detonator was placed at *a* and held firmly in position with putty. Heavy beams were placed in front of the door to arrest flying pieces. The nitroglycerin was detonated, and the effect produced was to rip out the door, right side, and bottom around the corner *b* to the depth of three plates. The nitroglycerin had run down between jamb-plates under the door, and hence had not risen high enough above the point *b* to get in behind the plates succeeding the third. The wheel *e* was knocked to pieces, and the corner *b* of the safe was driven down 1¼ inches into a pine flooring. Had the jamb plates been tight the nitroglycerin would have been located in the space between the door and jamb, and would have risen high enough above *b* to penetrate behind the inner plates of the door, and a similar result would have obtained as did with the Hall safe in the twenty-seventh experiment. The operation of removing the remaining plates of the door after this explosion, by wedges, could easily be performed in a short time.



THIRTY-THIRD EXPERIMENT.

A cartridge of forcite powder No. 1 was made up as follows: A tin paint-can 3¼ inches in diameter, and 2¾ inches high, was placed bottom up on a flat board. The top of the can had previously been removed. Around this were tied twelve sticks of forcite powder No. 1. Seven sticks of this powder were now made up into a bundle and the end placed on the bottom of the can. The whole cartridge was then wrapped with wire as compactly as possible. It weighed 9½ pounds. In the figures below are to be seen, first, base of cartridge showing can and twelve sticks of forcite powder. Second, elevation, showing general arrangement of cartridge in firing position.





The object of placing the can at the lower end of this cartridge was to provide an air space into which the gases of explosion would rush and produce a powerful ballistic effect on whatever body the cartridge should be placed. It was then set, can down, on top of the back of the 32-inch Corliss safe that had been used in the twenty-first, twenty-third, and twenty-sixth experiments. No tamping was used. The detonator was placed in the top of the middle stick of the upper bundle. The result of the explosion was to lengthen by a few inches the crack developed by the previous explosions, but it was not widened nor deepened as far as could be ascertained.

THIRTY-FOURTH EXPERIMENT.

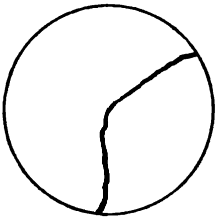
Five pounds of forcite powder No. 1 were made up in the shape of a cylindrical bundle of ten sticks and placed on end on the back of the 32-inch Corliss safe that was used in the twenty-first, twenty-third, twenty-sixth, and thirty-third experiments. No tamping was used and the detonator was placed in the top of the center stick.

As the result of this explosion the crack previously developed was extended 3 or 4 inches, deepened somewhat, but not appreciably widened.

THIRTY-FIFTH EXPERIMENT.

Ten pounds of forcite powder No. 1 were made up into two cylindrical bundles of ten sticks each. One was placed on end on the back of the 32-inch Corliss safe used in the twenty-first, twenty-third, twenty-sixth, thirty-third, and thirty-fourth experiments. The other was placed on end, firmly on top of this.

As the result of this explosion the crack was extended from side to side, as shown in the accompanying figure, but the section was not broken apart and the whole crack was not widened more than one thirty-second inch. The increase in depth could not be ascertained, but the section still held together.



THIRTY-SIXTH EXPERIMENT.

This was a repetition of the preceding experiment. As the result of this explosion the crack was perhaps widened perhaps a hairbreadth, but the section still held together.

THIRTY-SEVENTH EXPERIMENT.

Eight ounces of forcite powder No. 1, a single stick, were placed on end on top of back of Corliss safe used in preceding experiments. A detonator was placed in top of the stick. As the result of this explosion no further effect whatever was produced on the section.

THIRTY-EIGHTH EXPERIMENT.

Ten pounds of forcite powder No. 1 were made up into a cylindrical bundle of twenty sticks, were placed on end on top of the same back of Corliss safe, as was used in the preceding experiments. The forcite powder was frozen hard, with the exception of about 2 ounces which had been thawed out and which was placed as a priming charge on top of the center stick of the pile. In this the detonator was imbedded. The whole mass detonated violently.

As the result of this explosion a number of wedge-shaped pieces of iron were torn out along the crack previously developed, and in direction of the grain of the chill. These measured about 1 inch deep and from 2 to 3 inches long. They had been removed from that portion of the metal above the basket; but the latter still held the section together.

Reviewing these experiments, 21, 23, 26, 33, 34, 35, 36, 37, and 38, with high explosives on this back of the 32-inch Corliss safe, it will be observed that a total of 64 pounds 4 ounces of gun cotton and forcite powder No. 1 have been fired upon it, and yet it holds together.

	Lbs.	Oz.
Gun cotton:		
First	4	6
Forcite powder No. 1, 75 per cent nitroglycerin:		
Second	5	0
Third	10	0
Fourth	9	8
Fifth	5	0
Sixth	10	0
Seventh	10	0
Eighth	0	8
Ninth	10	0
Total	64	4

That the back should still hold together after such repeated heavy charges needs no comment on the strength of this construction.

THIRTY-NINTH EXPERIMENT.

The screw-door safe made by M. Briggs & Son, described in connection with the twentieth experiment, was laid on its face. A cartridge of forcite powder No. 1, made up precisely as the one used in the thirty-third experiment and weighing the same, was placed on top of the middle of the back. No tamping was used. The detonator was placed in the top of the center stick of the upper bundle.

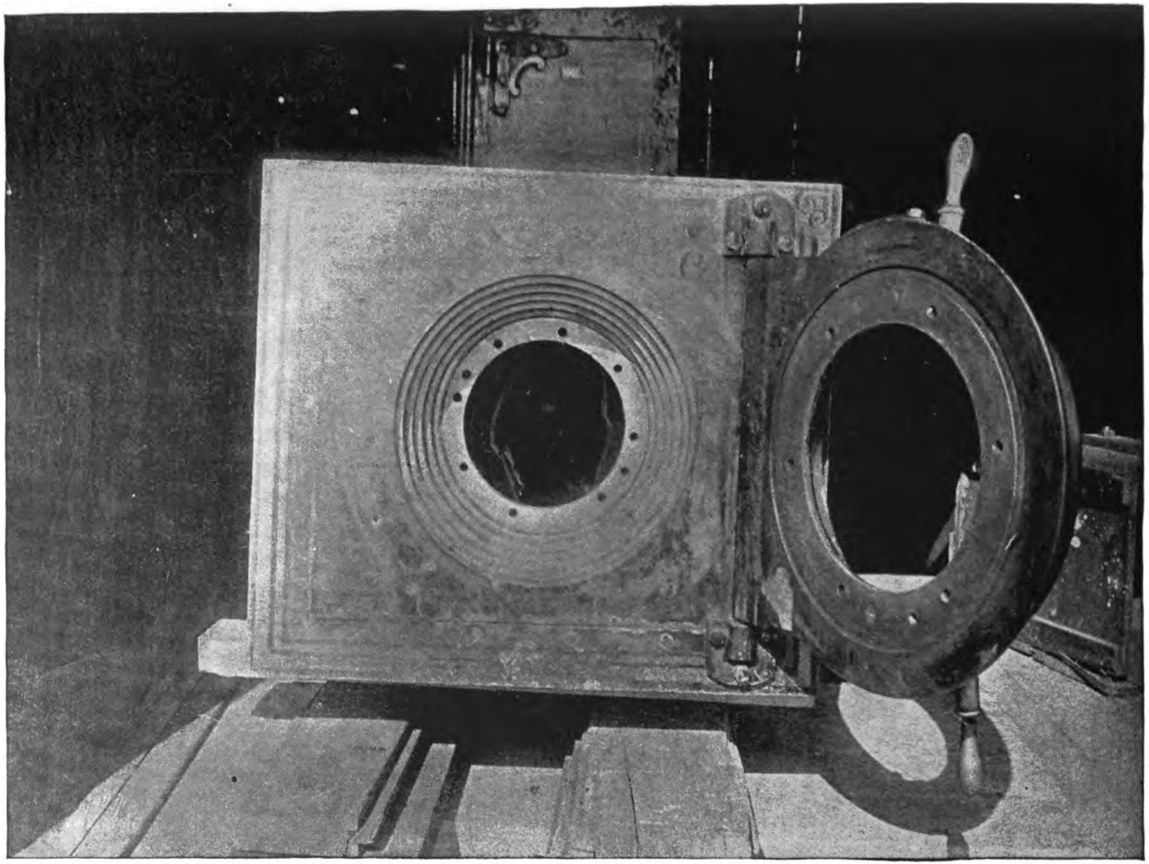
The result of this explosion was to dish in the back of the safe three-fourths inch. and to develop a small crack about one thirty-second inch wide and 1½ inches long through first plate. No hole nor crack was made in any of the succeeding plates. The thickness of this back made up of ten plates, alternate iron and steel, was 4¾ inches.

FORTIETH EXPERIMENT.

Another cartridge was now made up precisely as the last and weighed the same. This was placed, can down, in a 5-gallon tin can, and putty was pressed around the junction of the small with the large can in order to prevent any leaks into the small one. The whole arrangement was then placed on the same spot on the back of the screw-door safe used in the preceding experiment, where the previous charge had been. The detonator was placed as before, and the large can filled with water for a tamping. This tamping was about 3 inches thick, around and over the cartridge. The result of this explosion is shown in the accompanying photograph. The crack in the first plate was extended nearly across it, and was one-half inch wide at the middle point. The succeeding plates were torn and forced apart by the gases of explosion, which penetrated right through to the interior of the safe, which was then plainly visible. Considering the small area of the back, its rigid support on all four sides, and its thickness, the result produced by this explosion is astonishing. Had the area been increased, had the thickness been less, a very much larger opening would have been made, and if such a charge should be fired upon the door or sides of vaults ordinarily in use at the present time, it is probable that an opening would be made through which a man might enter. To show the great effect produced by this charge of 9½ pounds of forcite powder No. 1, a comparison can be made with the amount required to punch a hole through a wrought iron plate of the same thickness, viz, 3¾ inches. To punch a hole in a one-half inch wrought-iron plate requires 6 ounces of forcite powder No. 1. The charge increases with the square of the thickness; therefore to punch a hole in a 4¾ inch wrought-iron plate would require $33\frac{8}{10}$ pounds of dynamite, or forcite powder No. 1. The influence of the method of making up the cartridge of forcite powder, and of the water tamping, is here most signally shown; not less so is the weakness of laminated constructions proven.

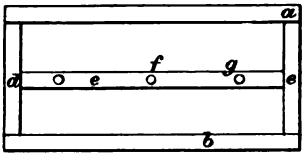
FORTY-FIRST EXPERIMENT.

This experiment was to determine the practicability and time required for going through the top of a safe into the interior. The safe used was made by Thompson & Co., New Haven, Conn. It measured [illegible]9 inches deep, 20¾ inches high, and 34 inches long. The back, door, and top were 3 inches thick; the sides, 3½ inches. There were ten layers of plates used in the construction of the top. The outside plate was of wrought iron. The second and third were made up of narrow steel strips laid perpendicular to the length. These were about 2 inches wide, and the

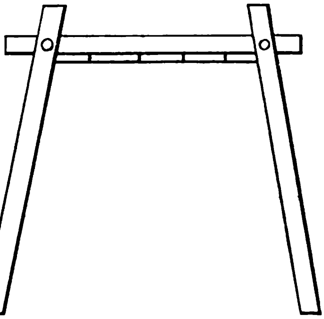


Screw Door Safe. Inside View through Door Opening, showing the Plates Torn and Forced Apart by the Explosion.

joints of one layer were covered by the plates of the other. The fourth plate was of wrought iron, made up of two pieces placed end to end. The fifth and sixth were the same as the second and third. The seventh was the same as the fourth. The eighth and ninth were the same as the fifth and sixth, and the tenth was the same as the seventh. The average thickness of each plate was three-tenths inch.

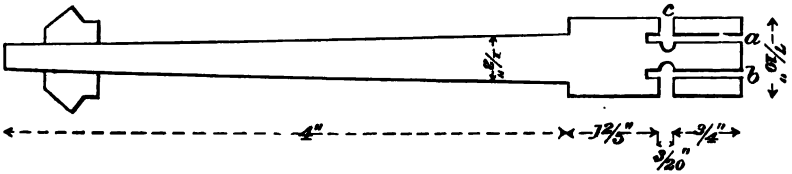


The figure represents the top of the safe with what might be termed the strap finish, *a* and *b* being iron straps about 2 inches wide and one-quarter inch thick, going entirely around the safe; *e* is a short strap of the same size as *a* and *b* bolted to the top of the safe; *c* and *d* are angle plates bolted to the top and sides of the safe. On account of the extremely cold weather the safe was warmed by the application of the blowpipe in order that the nitroglycerin used should run freely when it came into contact with the metal. The first operation, performed in less than a minute, was to wedge off the strip *e*. Around the three small bolts which had held this strip, wells of putty were made, and into each were poured one-twelfth ounce of nitroglycerin, which rapidly ran down under the first plate. Two detonators connected in series were used, one at *f*, the other at *g*. An iron plate was laid on top of the safe, and over this 3 bushels of sand in sand bags. A light wooden frame, shown in the following figure, supported an inverted platform about 4 feet above the top of the safe. Its object was to arrest flying pieces.



The whole arrangement stood on the floor, but was not fastened to it. The uprights and the cross pieces were made of 3 by 4 inch stock and the flooring of the inverted platform of 2-inch planks.

As the result of this explosion the first plate was lifted off and the steel strips throughout were shattered into small fragments. The remaining iron plates were so loosened that they and the steel strips were easily and quickly removed, wedges only being used, and an opening on the right portion of the top, 10 by 12 inches, right into the safe, was made in 25 minutes from the time that the strip *e* was pried off. The inverted platform was overturned, but not injured. The tamping was particularly effective in directing the force of the explosion downward, thus causing the under plates to be so loosened from their fastenings that it was an easy matter to remove them. As for the steel strips, they were practically worthless as a protection against burglars. A sledge hammer would have broken them like glass.



The following set of experiments was made upon the center spindle of the Corliss safe door. Its general shape and dimensions are shown in the accompanying figure.

The upper part is made of chrome steel, and is welded to the lower part, made of Norway iron. It was set up in a block of chilled iron, which, of the same thickness and construction as the door itself, was bored out to receive it. The bronze geared nut as shown in the figure was screwed on as in the lock proper.

FORTY-SECOND EXPERIMENT.

In a well of putty made around the top of the spindle one-fourth of an ounce of nitroglycerin was poured. A portion of this ran down through the small holes *a* and *b* and into the annular space *c*. The whole charge was water-tamped and a detonator placed in the nitroglycerin that remained on top of the spindle.

As the result of this explosion the head of the spindle was knocked off, but the remainder of it and the bronze geared nut remained firm. It was with difficulty driven out from underneath with a sledge hammer after the bronze geared nut had been unscrewed. It was then seen that the gases of explosion had penetrated down around the spindle to this nut, but the fit of the spindle was so close that not enough could get by to produce any ballistic effect in removing it.

FORTY-THIRD EXPERIMENT.

The spindle was replaced, the bronze geared nut was screwed on, and the recess over the spindle which had been occupied by the spindle head was filled with one-sixth of an ounce of nitroglycerin, tamped with water, and fired.

As the result of this explosion the spindle was driven down about one-sixteenth of an inch, but was not broken, nor was the bronze geared nut removed. It was then found to be impossible to drive the spindle out from the inside with a sledge, so firmly was it wedged in its position.

FORTY-FOURTH EXPERIMENT.

A well of putty was built around the spindle hole. Into this and the recess which had been occupied by the spindle head one-third of an ounce of nitroglycerin was poured. This was tamped with water and fired. The explosion produced no effect whatever, either on the spindle, the bronze geared nut, or the block of iron.

FORTY-FIFTH EXPERIMENT.

In the recess which had been occupied by the spindle head was tightly packed one-third ounce of Noble's explosive gelatine and fired. The result of this explosion was to drive the spindle down about one thirty-second inch, but it was not broken, nor was the bronze geared nut driven off.

FORTY-SIXTH EXPERIMENT.

This was a repetition of the preceding experiment, and no effect whatever was produced upon the spindle.

The conclusion reached from a review of these five experiments, forty-two to forty-six, inclusive, is that the Corliss spindle is proof against an attack with high explosives.

FORTY-SEVENTH EXPERIMENT.

The safe made by Thompson & Co., New Haven, which was used in experiment No. 41, was set up with the door in its natural position, *i. e.*, vertical, and an attack made upon the spindle as follows: The door was closed and bolted; it could not be locked because the spindle had rusted so that it could not be turned to throw off the combination. A well of putty was built up around the spindle, and three-fourths of an ounce of nitroglycerin was poured into it. This was allowed to stand five minutes, and some of it ran in around the spindle. A detonator was then placed in the pool of nitroglycerin in the well and fired.

As the result of this explosion the first three plates of the door were blown off and swung back on their hinges. The concussion sprung the bolts back, and the remainder of the door dropped out to the front. The spindle was not broken, but was driven in so as to knock off a portion of the combination lock. The entire operation occupied about ten minutes. The portion of the door with bolts was now replaced and one-third of an ounce of nitroglycerin applied to the spindle as before and fired.

As the result of this explosion three more plates of the door were blown off bodily. The spindle was broken off and driven in so as to shatter the combination lock. What remained of the spindle was now driven through with a small hammer and punch, and a hole 1 inch in diameter was left through which to operate with an explosive and blow the door out, in case the spindle should not knock the combination lock entirely off when driven in, as happened in this instance. If the combination lock is knocked off, as will obtain in many cases, then the only obstruction to the bolts is removed, they can be turned back, and the door opened from the outside. There was very little noise from the explosion.

Reviewing this experiment, we conclude that the spindle of a square safe can be successfully attacked in a practically burglarious manner. From the very construction of laminated safes it is impossible that the fit should be close. This can and does obtain with the Corliss spindle.

SAMUEL RODMAN, JR.,
First Lieutenant, Second U. S. Artillery.

MECHANICAL BURGLARY.

In view of the fact that the Treasury commission while here witnessed the operation of cutting a hole 4 inches in diameter by hand entirely through the 4-inch wall of a Herring Champion, burglar-proof, in four hours and twenty-two minutes, also the operation of stripping a safe, plate by plate, by the use of chisels and wedges, we have thought that it would not be inappropriate for us to furnish the commission with the following photographic illustrations, representing the result of a multitude of practical operations that have been performed by us upon different specimens of laminated safe construction.

The ease and rapidity with which these operations can be performed is well calculated to surprise and astonish the fraternity of bankers, whose whole education has been to believe that such operations are impossible.

In looking over these photographs the fact should be borne in mind that in every instance the work done has been performed by hand and by the use of implements that it is perfectly fair to assume that burglars might possess and make use of. It should also be remembered that every hole shown represents a practical burglary.

In most cases these demonstrations have been made in the presence of bank officials, who have visited our works from time to time for the purpose of witnessing the operation.

PHOTOGRAPH NO. 7.

The holes represented in this "burglar-proof" are all 4 inches in diameter.

Those passing through the steel chest are 6½ inches in depth.

Time occupied in making the different holes, from two and one-half to four hours.

All done by hand, and in a burglarious manner.

PHOTOGRAPH NO. 8.

The upper jamb of the door of this safe was blown away by dynamite inserted into the joint of the door, while the door was closed and locked.

By a subsequent charge the inner chest was blown open and the outer door blown off.

PHOTOGRAPH NO. 9.

Illustrating the mechanical attachment for cutting 4-inch holes, adapted to safes of different sizes.

PHOTOGRAPH NO. 10.

The operation of cutting in progress.

PHOTOGRAPH NO. 11.

We think it reasonable to assume that no explanation of this photograph is necessary. The practical value of the 4-inch hole is clearly shown.

PHOTOGRAPH NO. 12

illustrates a 9-ton safe from the Eutaw Savings Bank, Baltimore, Md. The holes on the edge of the door were made by cutting off the outside plate by 4-inch cutters and afterwards drawing the temper and drilling through the conical bolts that hold the bolt frame.

This operation was repeated four times, as indicated, each time requiring about one hour. Each hole practically opened the safe.

The 4-inch holes shown were made in about three and one-half hours each.

PHOTOGRAPH NO. 13.

Illustrating the same safe as shown in photograph No. 12.

PHOTOGRAPH NO. 14.

Illustrations 14 to 19, inclusive, represent an unusually heavy safe, having double doors and 6-inch sides. Although this safe weighs six tons, and cost over $3,000, its available capacity is only about two cubic feet.

Our second experiment upon this safe was cutting a hole about four inches in diameter into the door until we reached the inner plate, which was of iron.

Time occupied, three and one-half hours.

We then put a rope about the safe, as shown in Fig. 15, and inserted a wire having a quarter-ounce cartridge of dynamite attached to it. The cartridge was fired by the man on top of the safe, as shown, by means of a pocket battery.

The result of the explosion is shown by photograph No. 16.

A close examination of Fig. No. 17 shows that the bolt frame was nearly displaced by the explosion, several of the bolts being broken.

The door came out by reason of the fact that the force of the explosion tore out the jamb of the door, as shown in Fig. No. 17.

PHOTOGRAPHS 18 AND 19

Represent our first experiment on this safe, which was the cutting of a 4-inch hole through the back, as shown.

On top of the safe, Fig. 18, may be seen the several discs of metal cut out in this operation, as well as those made in cutting the opening through the door.

PHOTOGRAPHS 20 AND 21.

Photographs 20 and 21 represent a safe that was sent to us in its locked condition.

A 4-inch hole in the side of the safe was made in two and one-half hours, the lock disconnected, as shown, and the door opened.

We were ignorant of the fact that there was a steel chest in the safe until we opened the door. We subsequently cut a hole in the steel chest, as shown in Fig. 22.

Since these photographs were taken we have made a number of 4-inch holes in the door, sides, and back, in fact, we have used it to experiment upon whenever bankers wished to witness this operation.

PHOTOGRAPHS 23, 24, 25, AND 26.

These represent another specimen of laminated construction.

As will be seen, a number of 4-inch holes have been cut through the sides, back, and door of this safe.

A number of small holes have been drilled through the conical bolts as shown. One of these holes was put through in twenty-nine minutes and thirty seconds.

PHOTOGRAPHS 27 AND 28.

These represent another so-called "Burglar-proof," the walls of which have been penetrated by 4-inch holes.

This illustration also shows the process of stripping the metal of the walls by chisels and wedges. The prominent corner shown in Fig. 28 illustrates what was done in one hours' time, the hole penetrating entirely through.

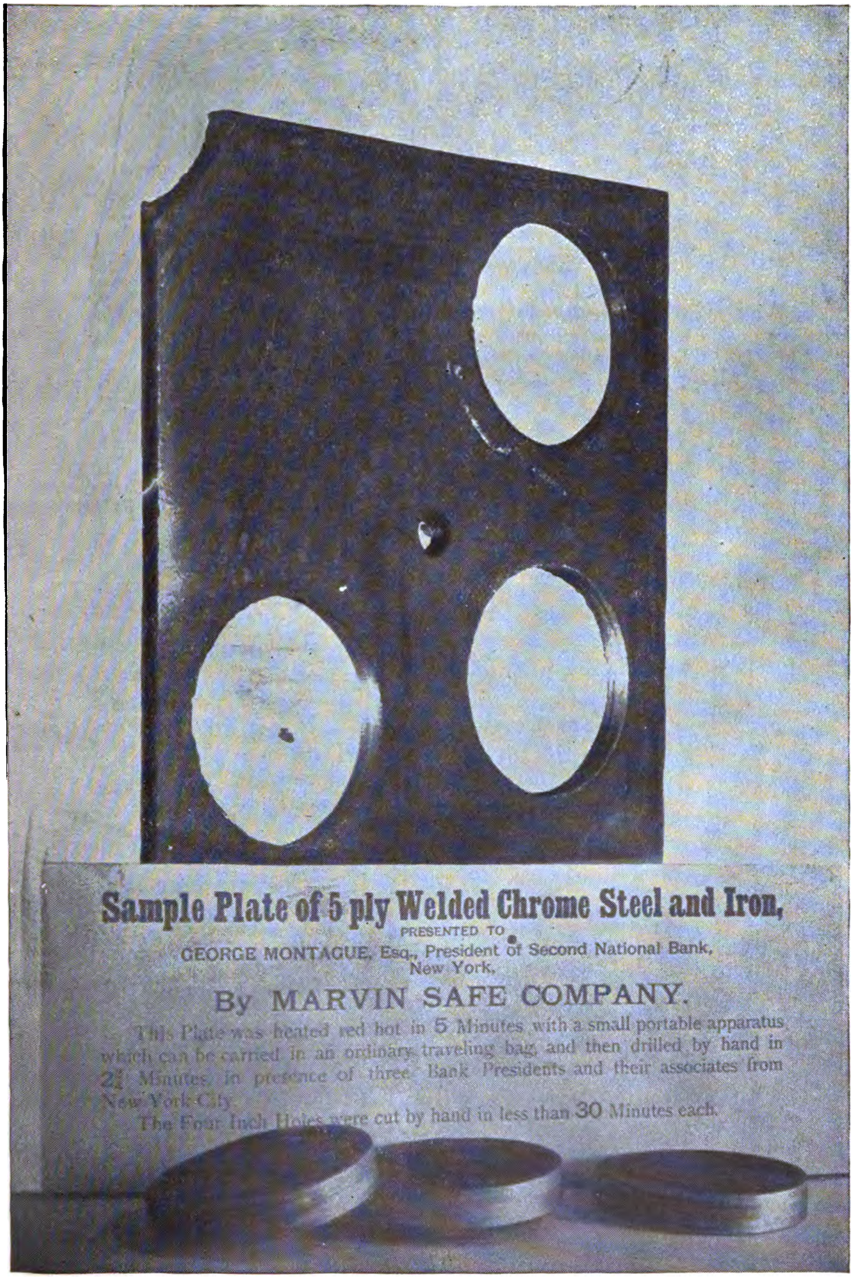
Fig. 37 shows a similar treatment of the front corner and upper corner of the door

PHOTOGRAPH 29.

This photograph represents what was done by two hours and fifty minutes' work of two men with sledges and chisels and wedges.

The multitude of rivets and other fastenings show that this safe was carefully constructed and very thoroughly put together. As will be seen, not only the side wall of the safe, but the inner steel chest was entirely removed.

When operated upon this safe was of course closed and locked.



Sample Plate of 5 ply Welded Chrome Steel and Iron,

PRESENTED TO

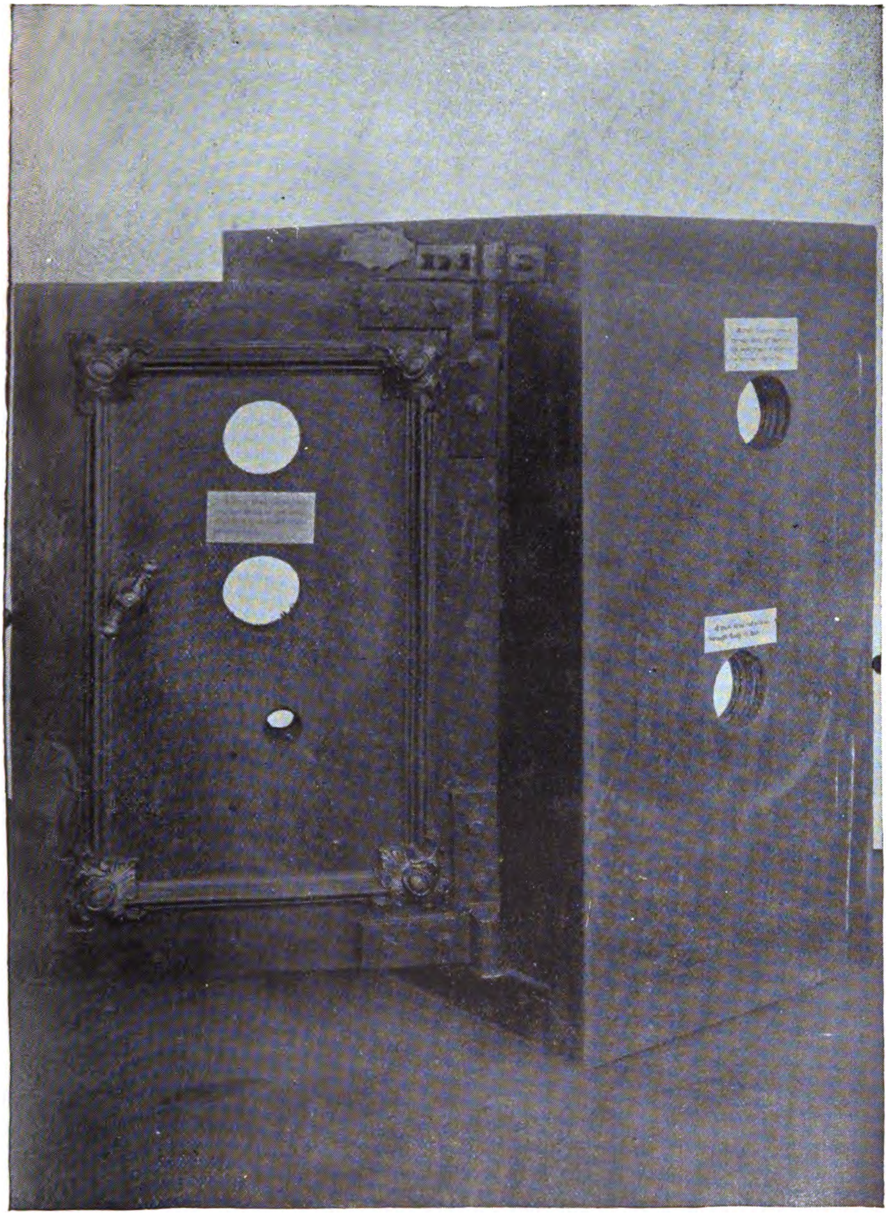
GEORGE MONTAGUE, Esq., President of Second National Bank,
New York.

By MARVIN SAFE COMPANY.

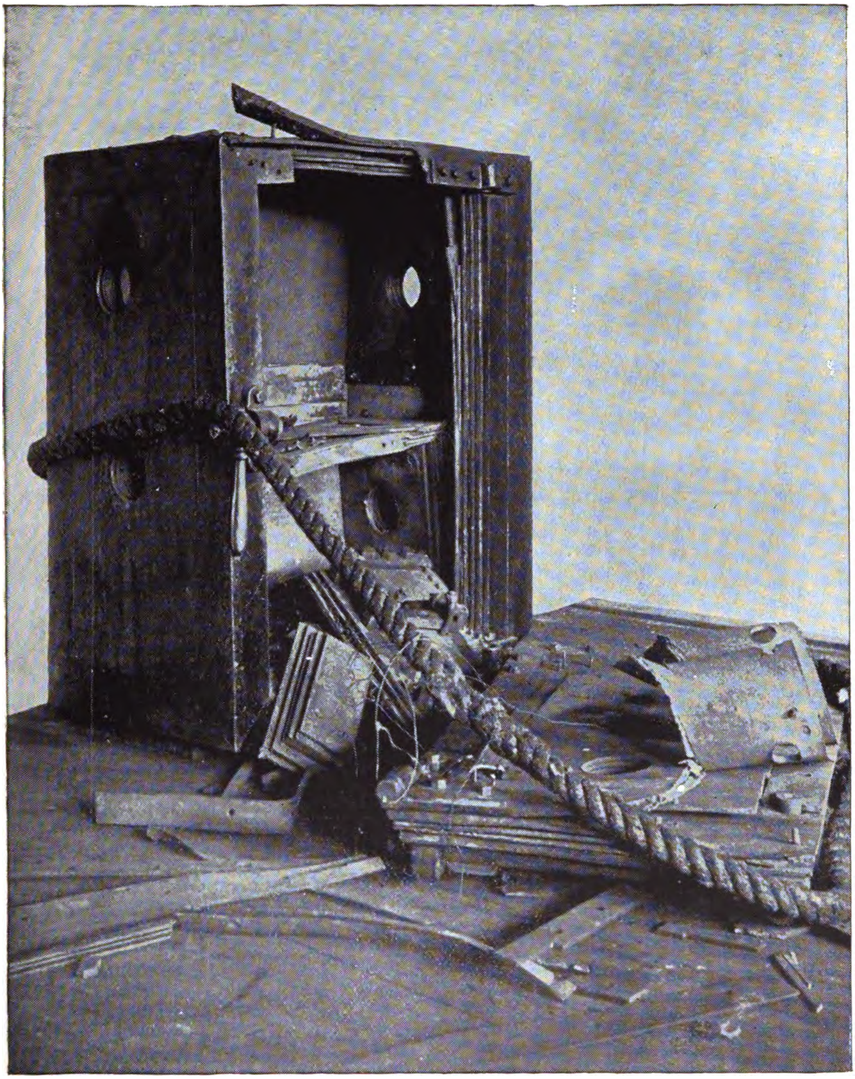
This Plate was heated red hot in 5 Minutes with a small portable apparatus which can be carried in an ordinary traveling bag and then drilled by hand in 2½ Minutes in presence of three Bank Presidents and their associates from New York City.

The Four Inch Holes were cut by hand in less than 30 Minutes each.

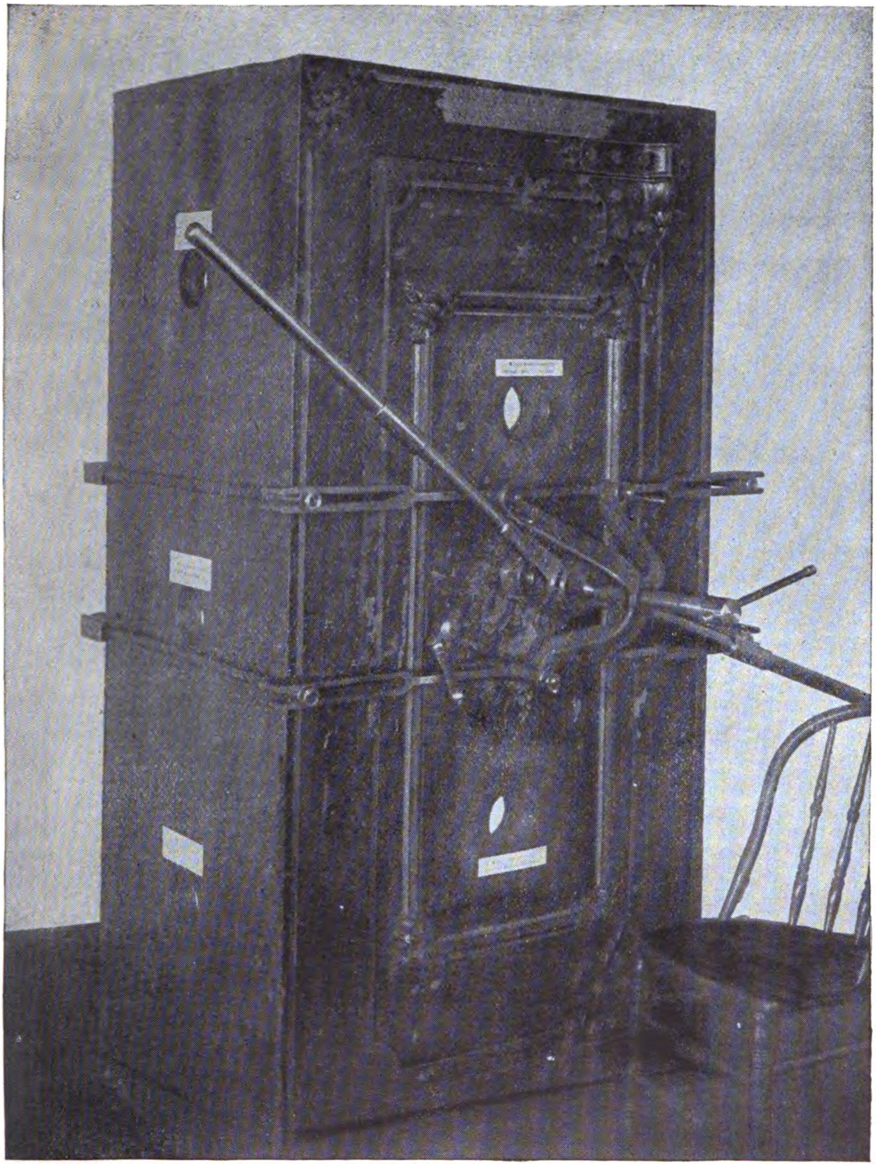
PHOTOGRAPH NO. 6.



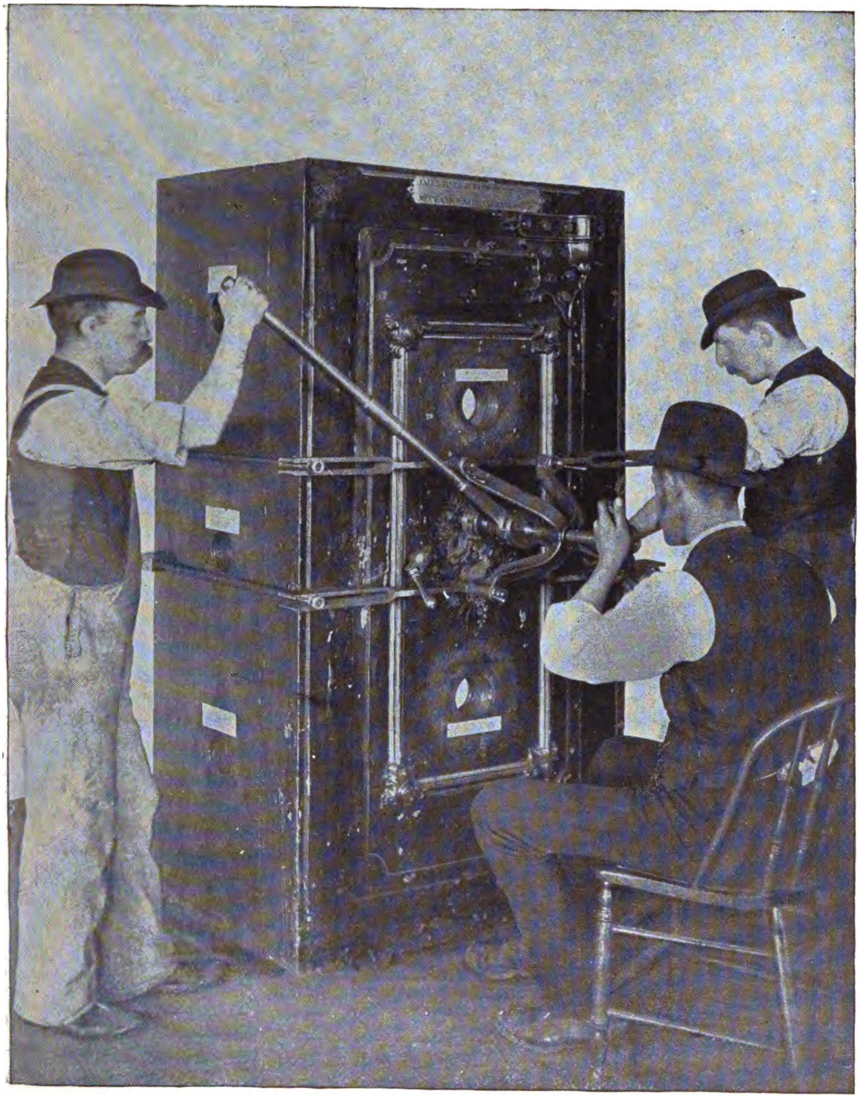
PHOTOGRAPH No. 7.



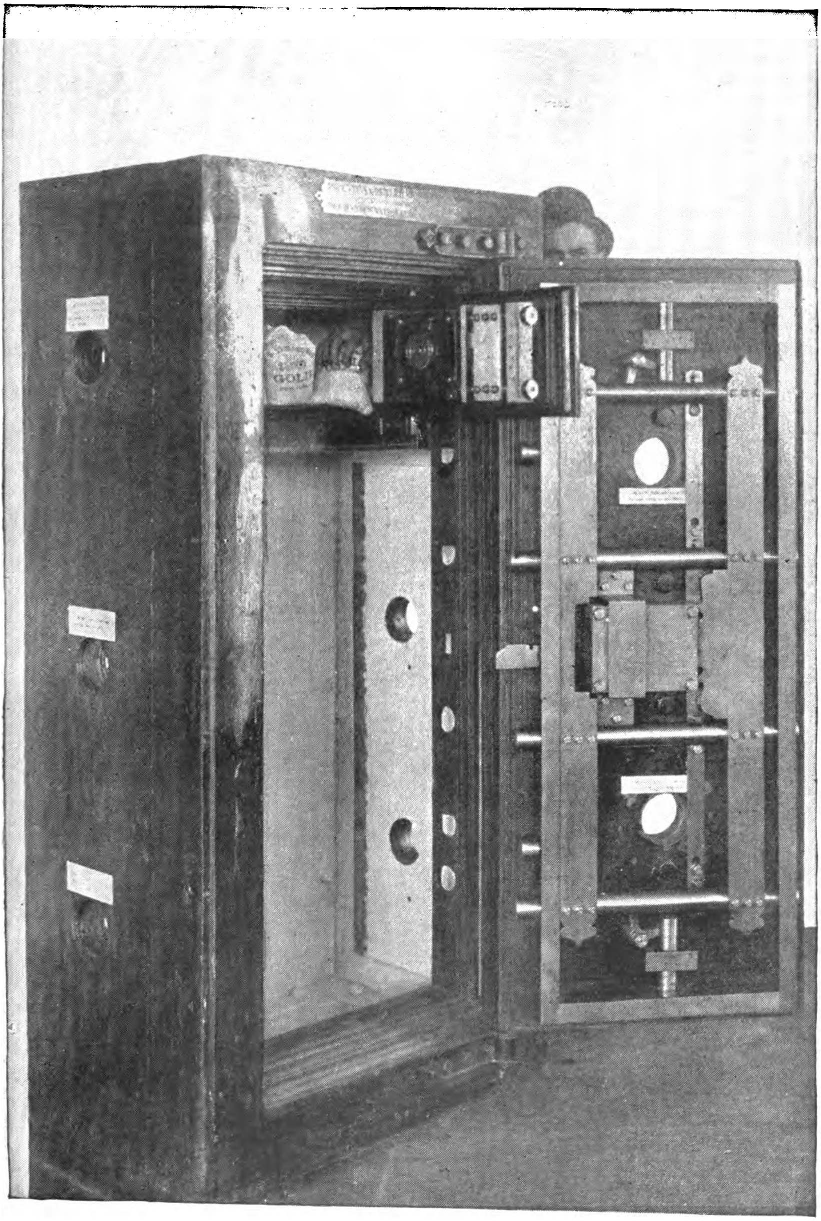
Photograph No. 8.



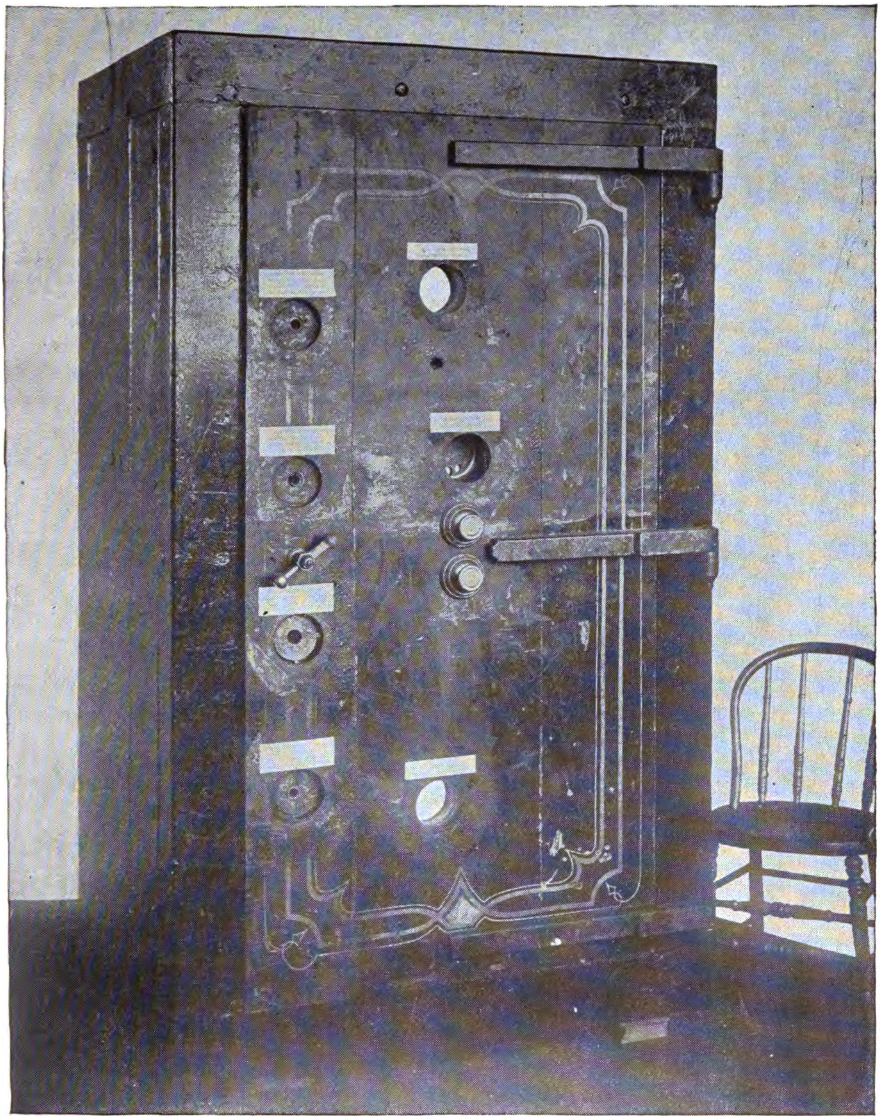
PHOTOGRAPH NO. 9.



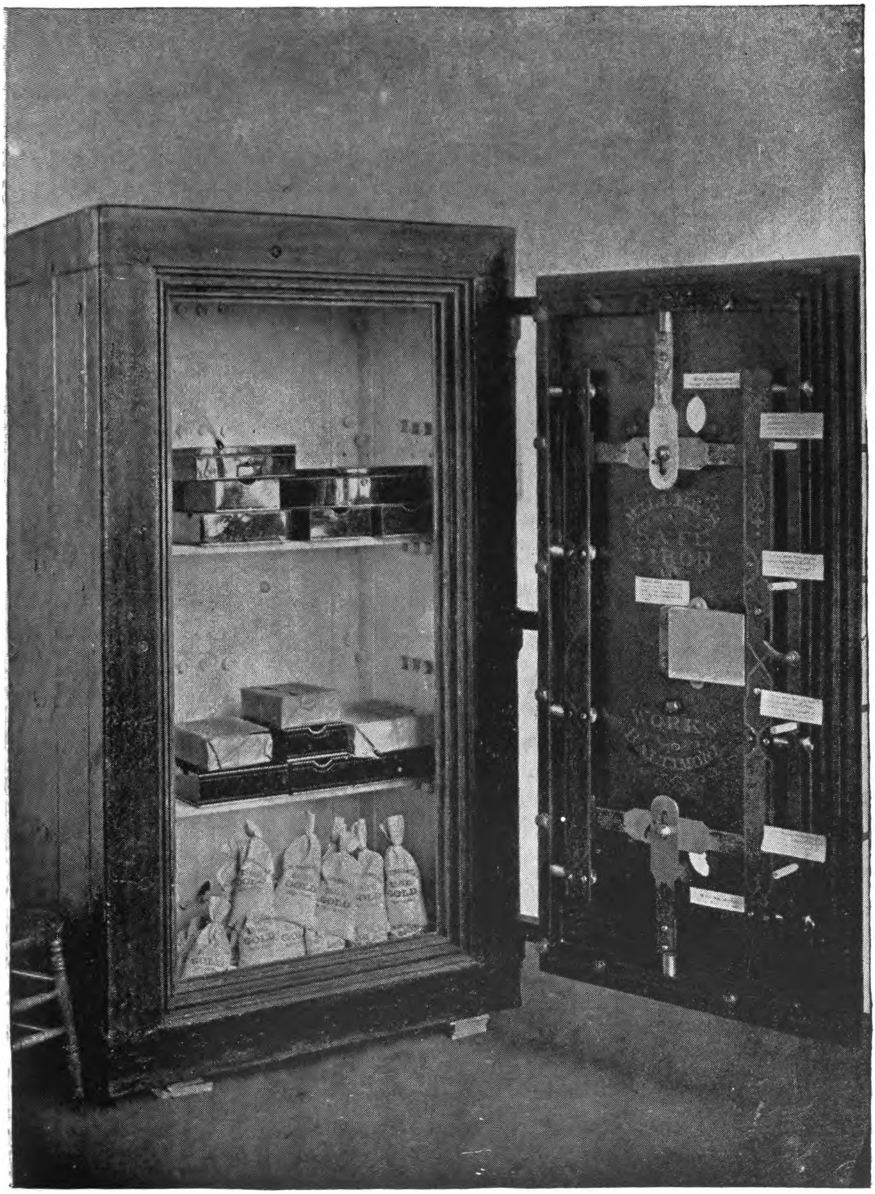
Photograph No. 10.



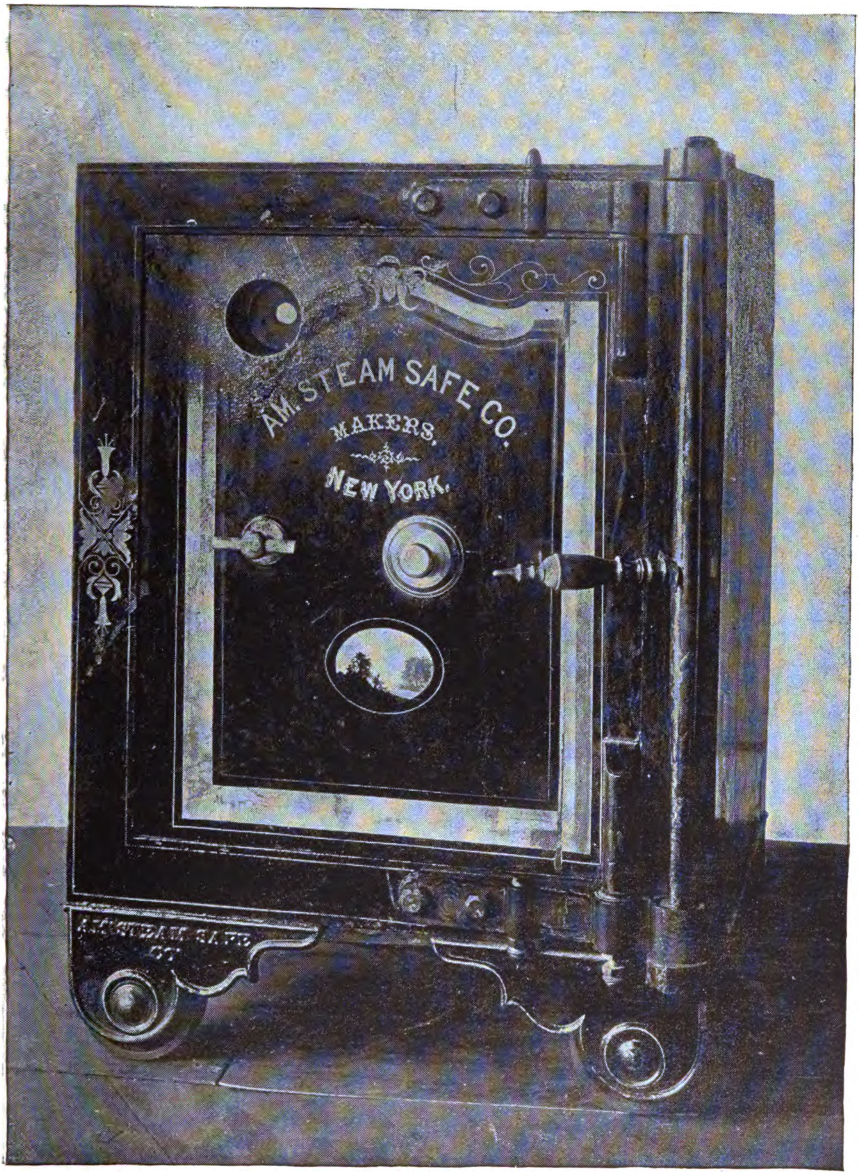
Photograph No. 11.



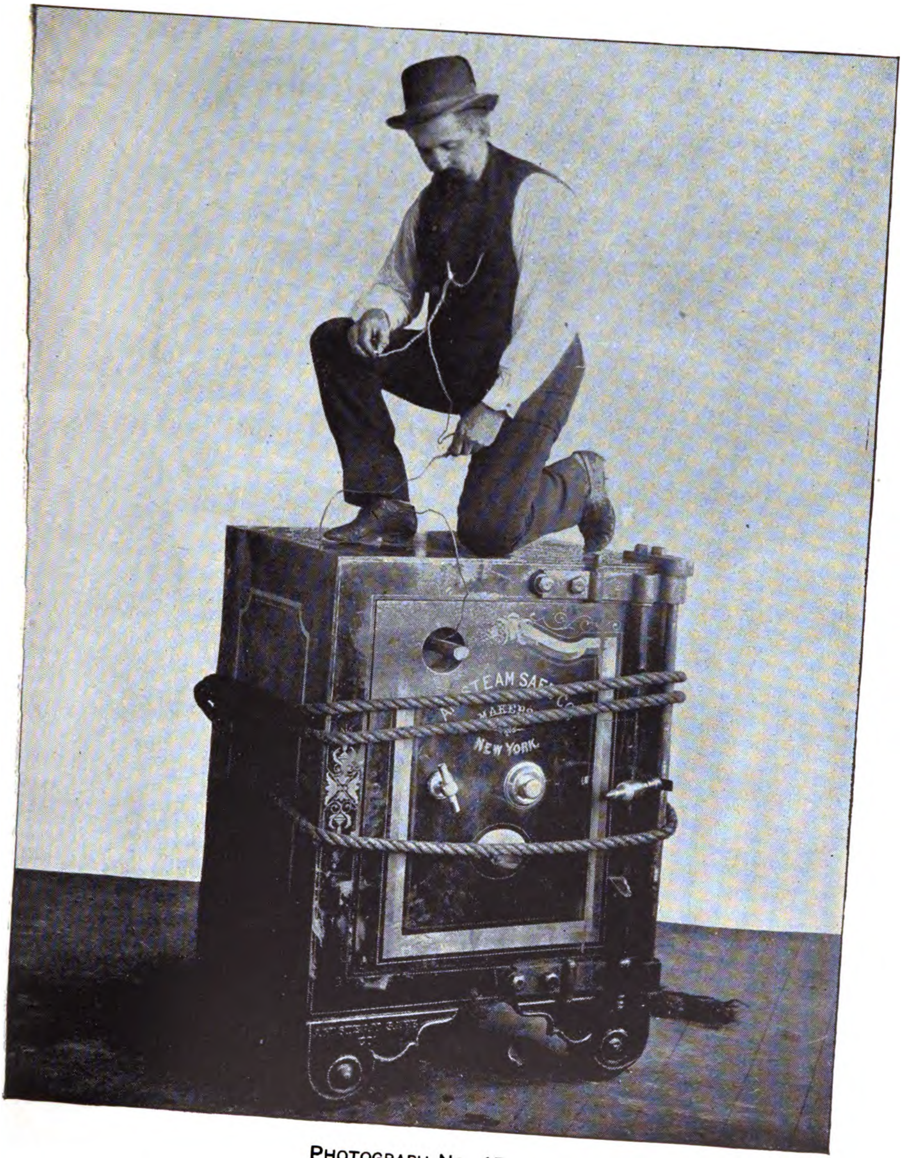
Photograph No. 12.



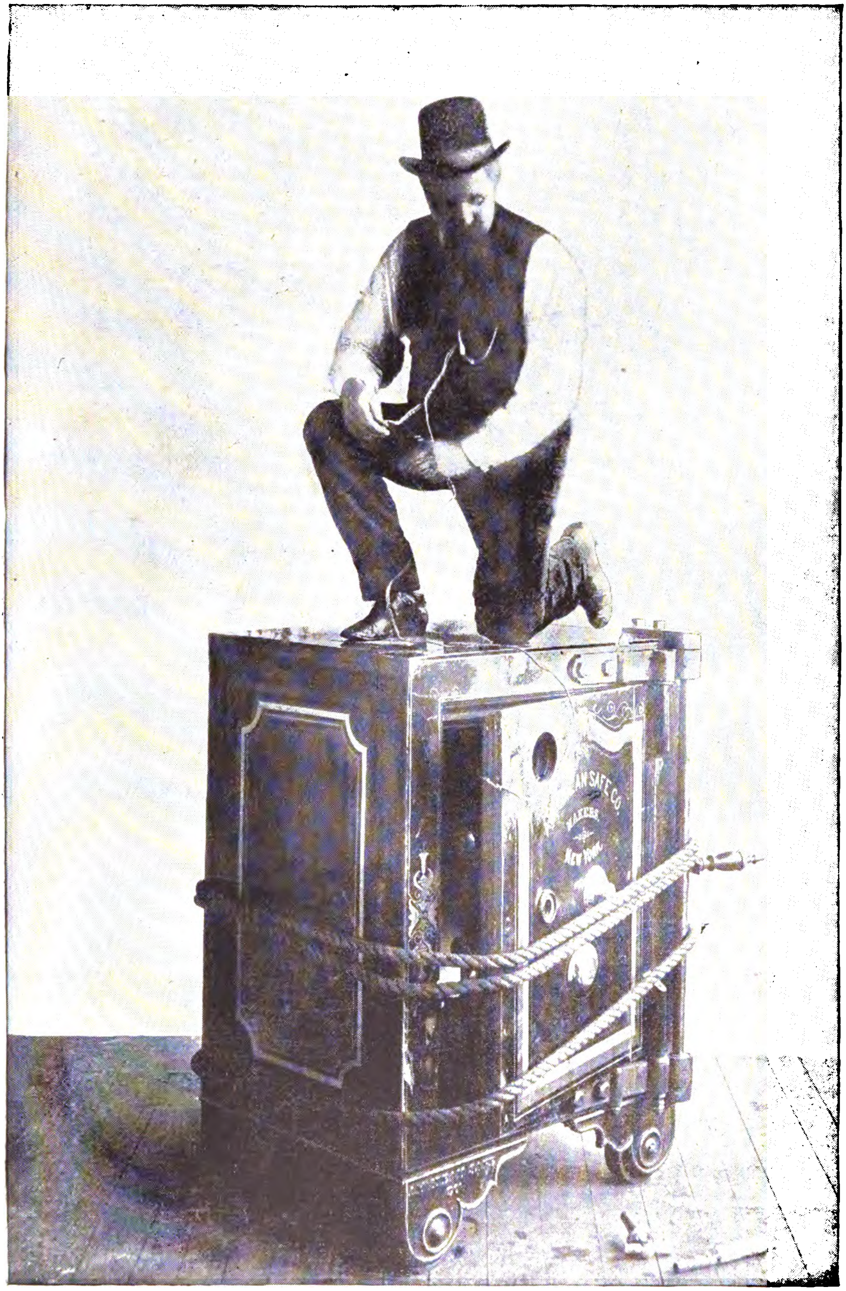
PHOTOGRAPH NO. 13.



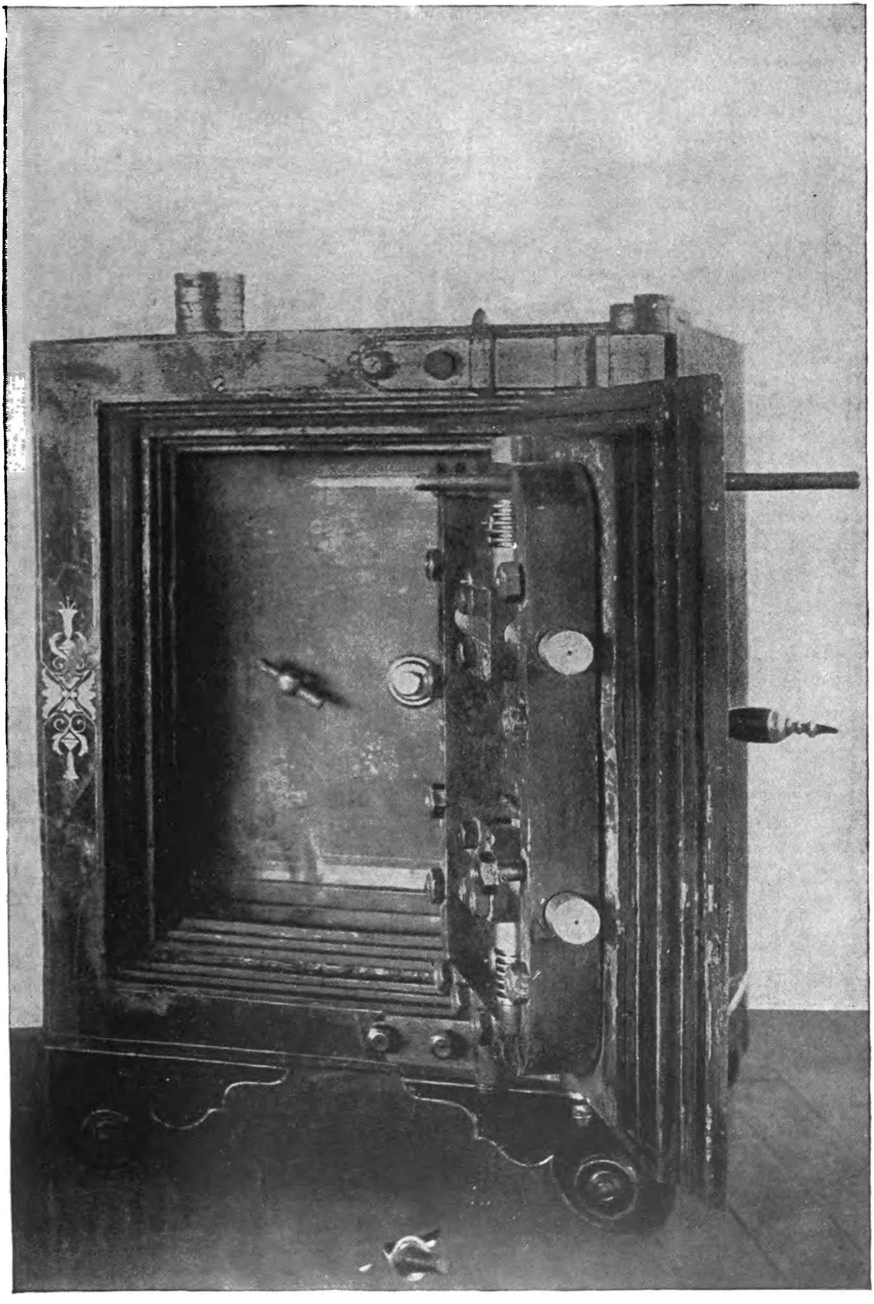
PHOTOGRAPH NO. 14.



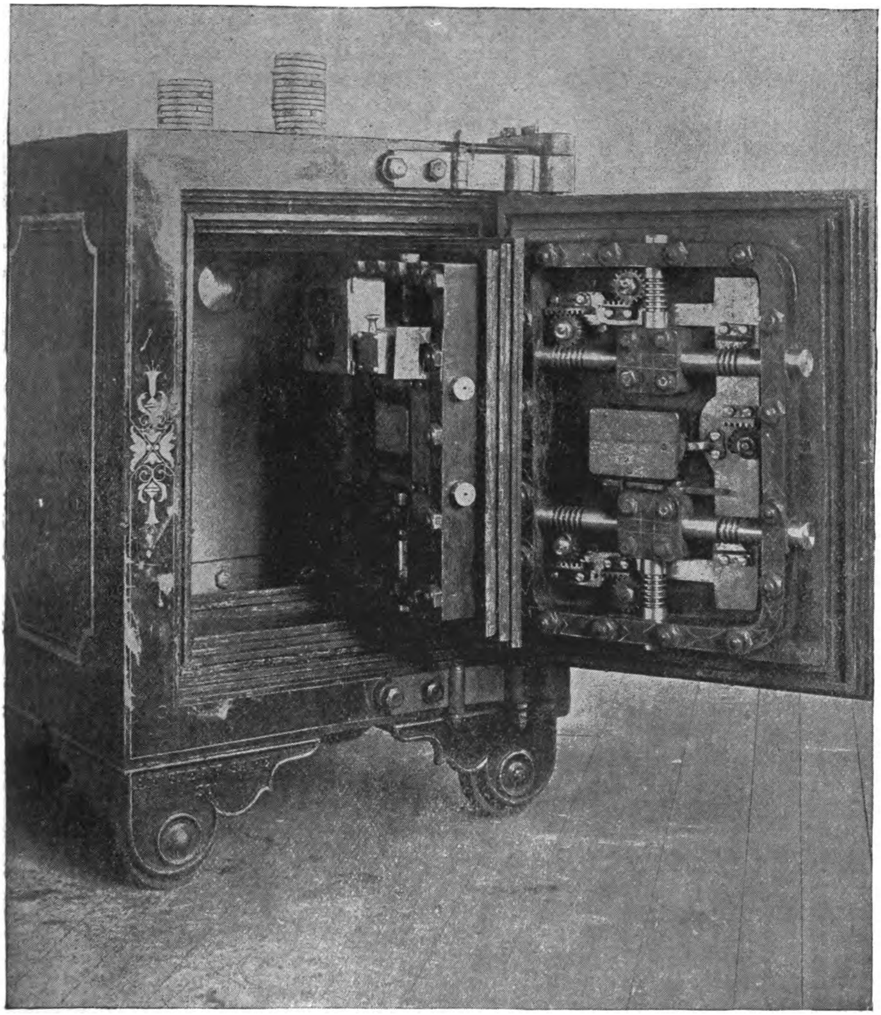
PHOTOGRAPH NO. 15.



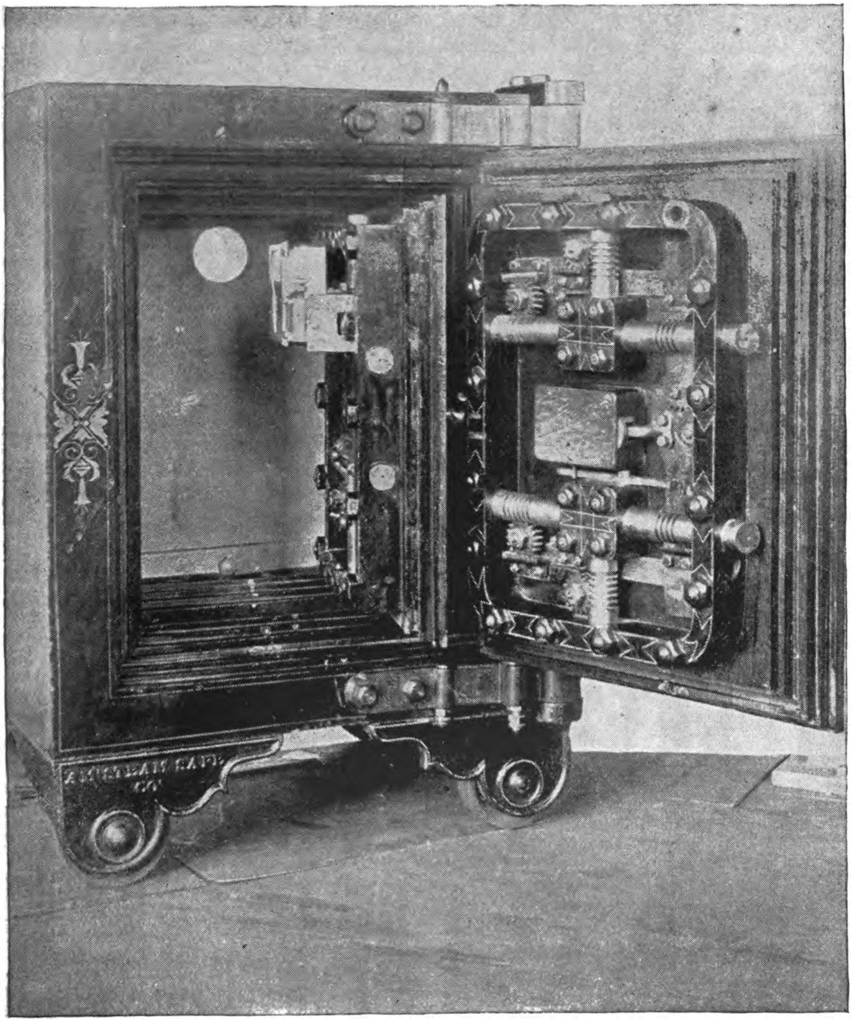
PHOTOGRAPH NO. 16.



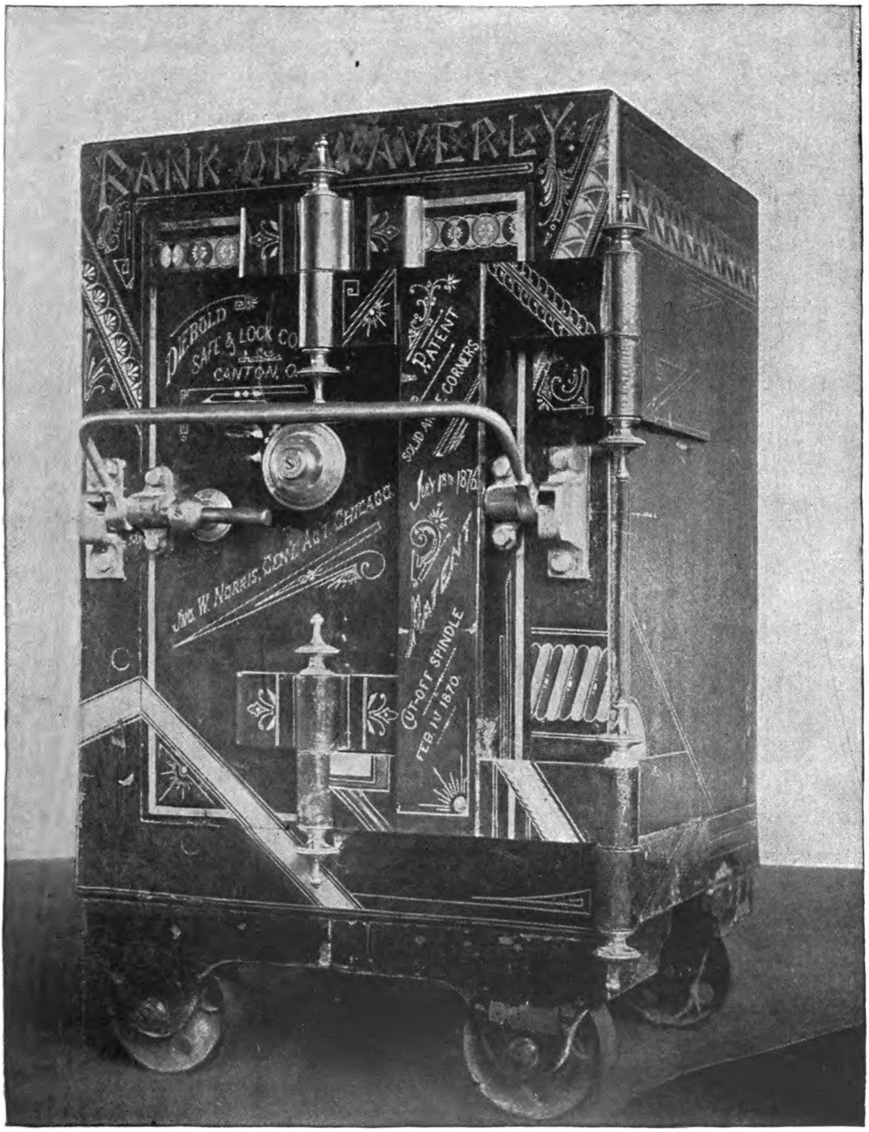
Photograph No. 17.



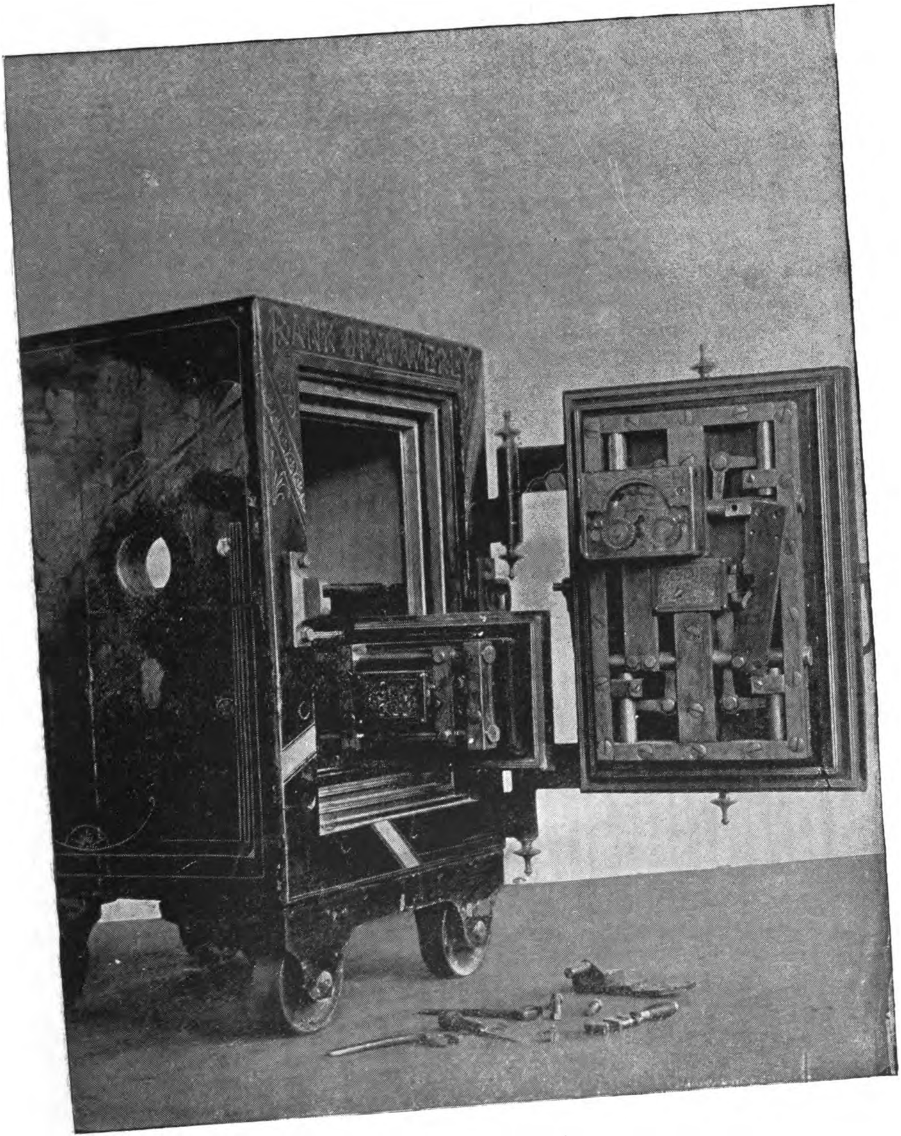
PHOTOGRAPH No. 18.



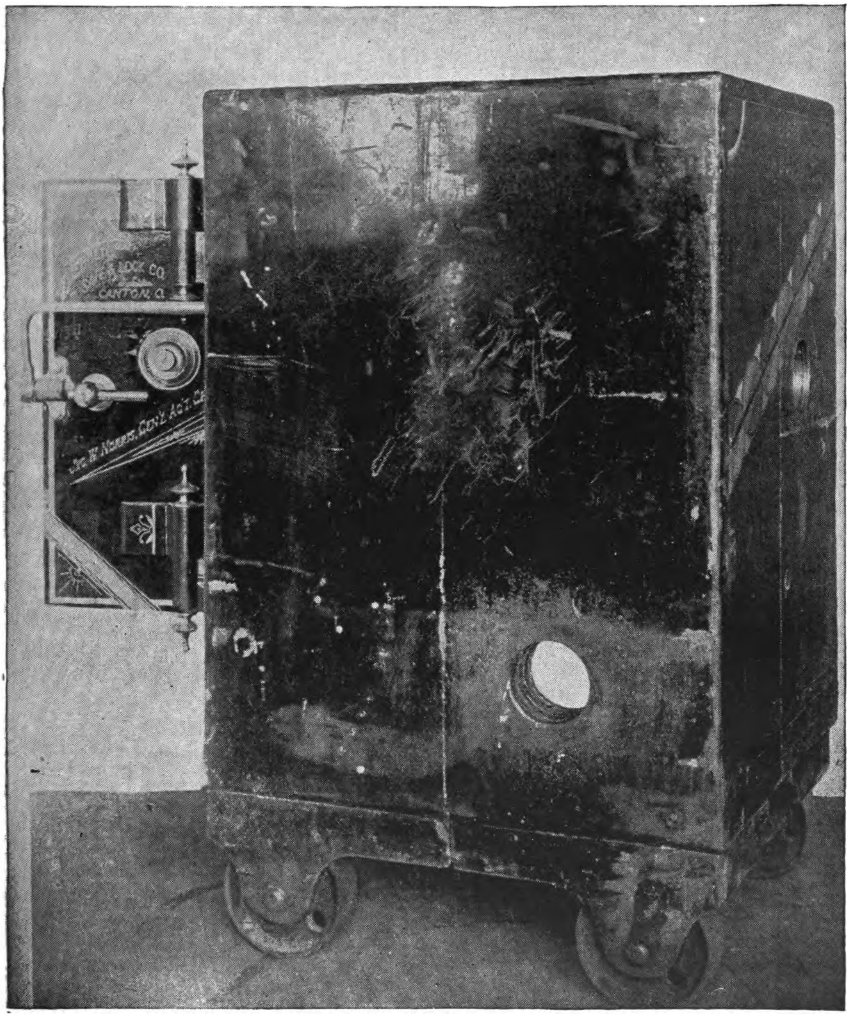
Photograph No. 19.



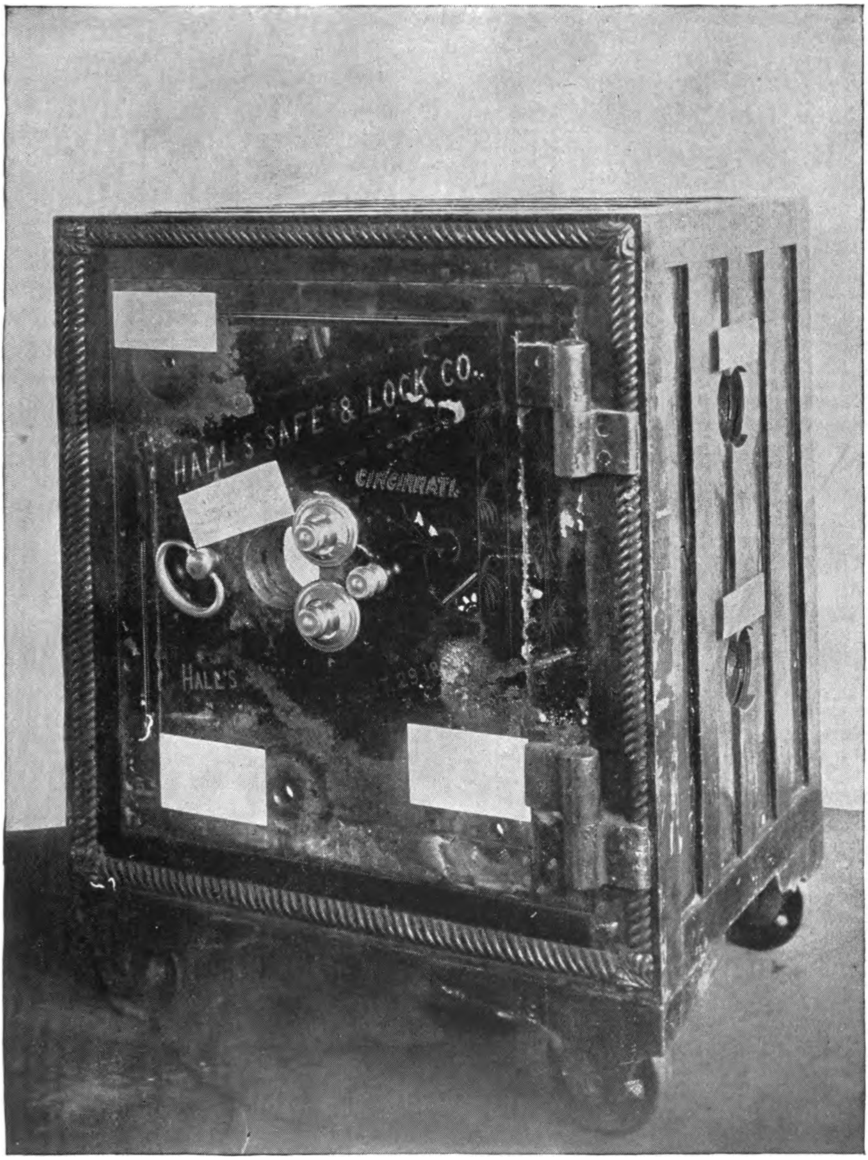
Photograph No. 20.



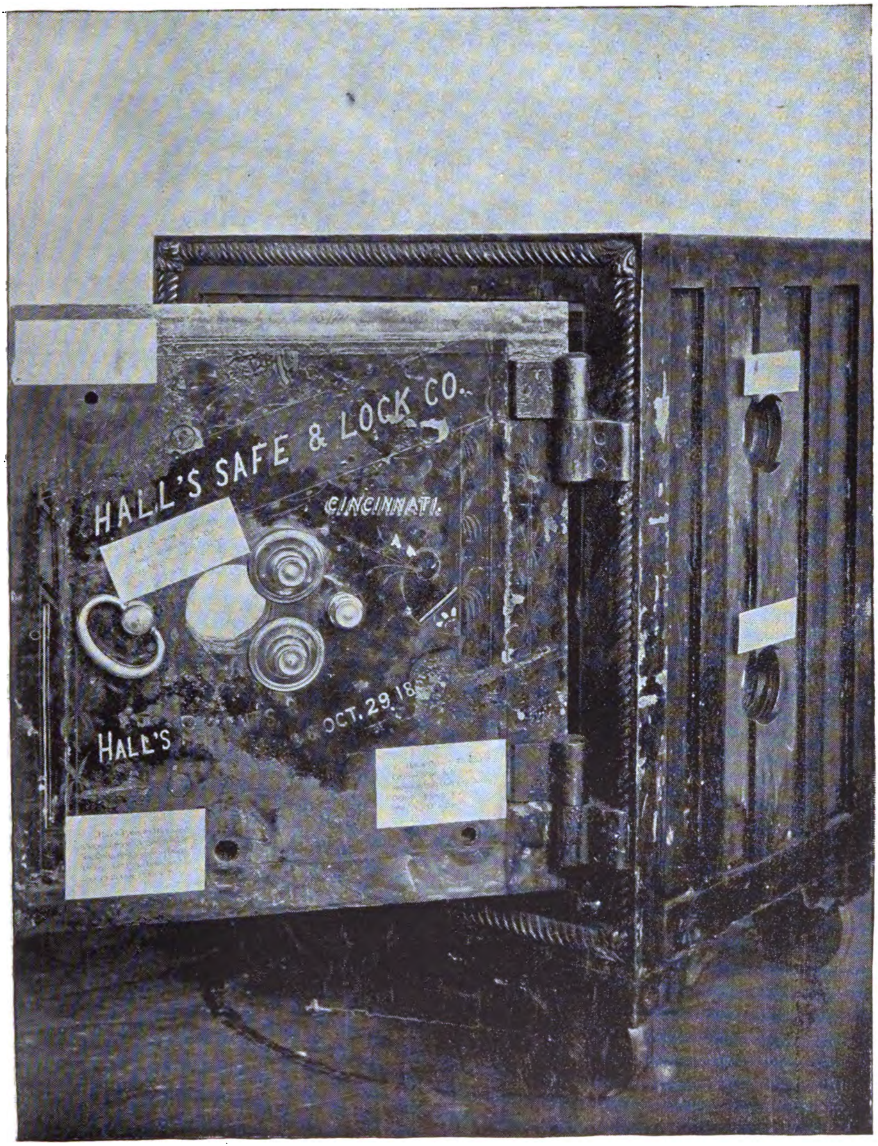
Photograph No. 21.



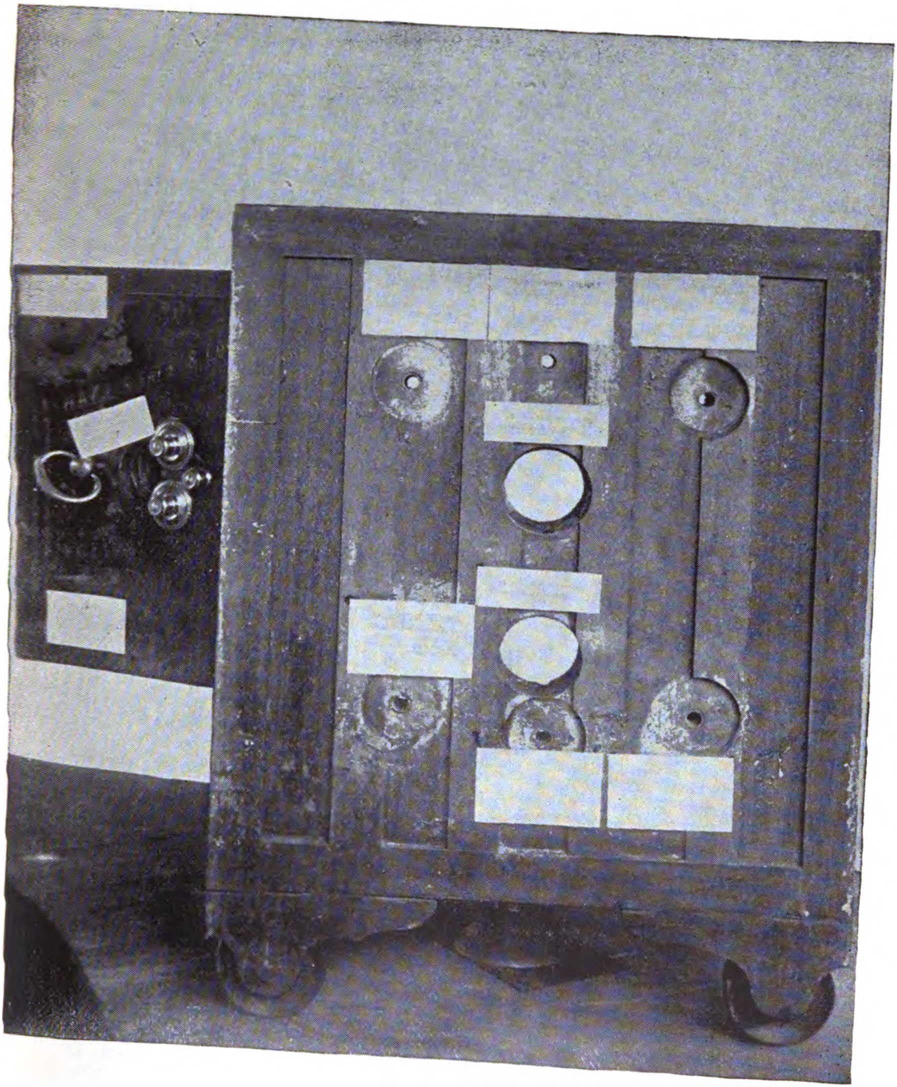
PHOTOGRAPH NO. 22.



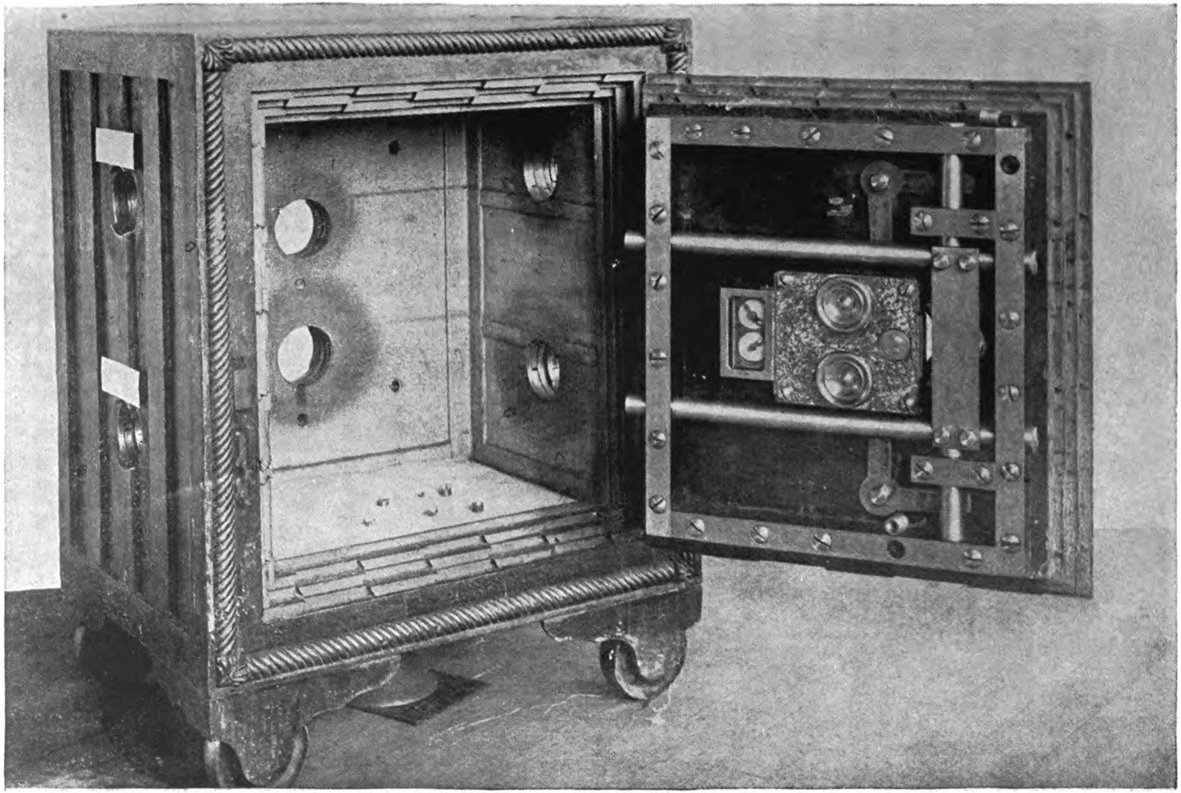
PHOTOGRAPH NO. 23.



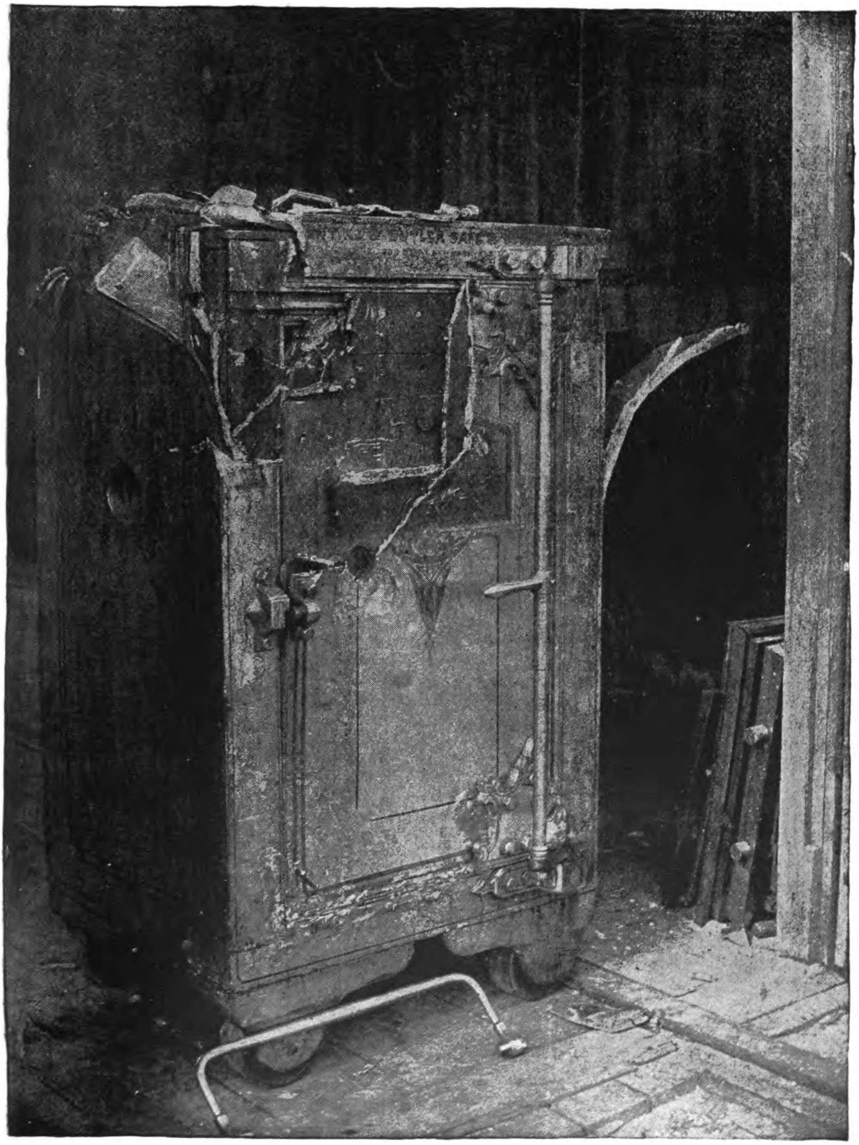
PHOTOGRAPH No. 24.



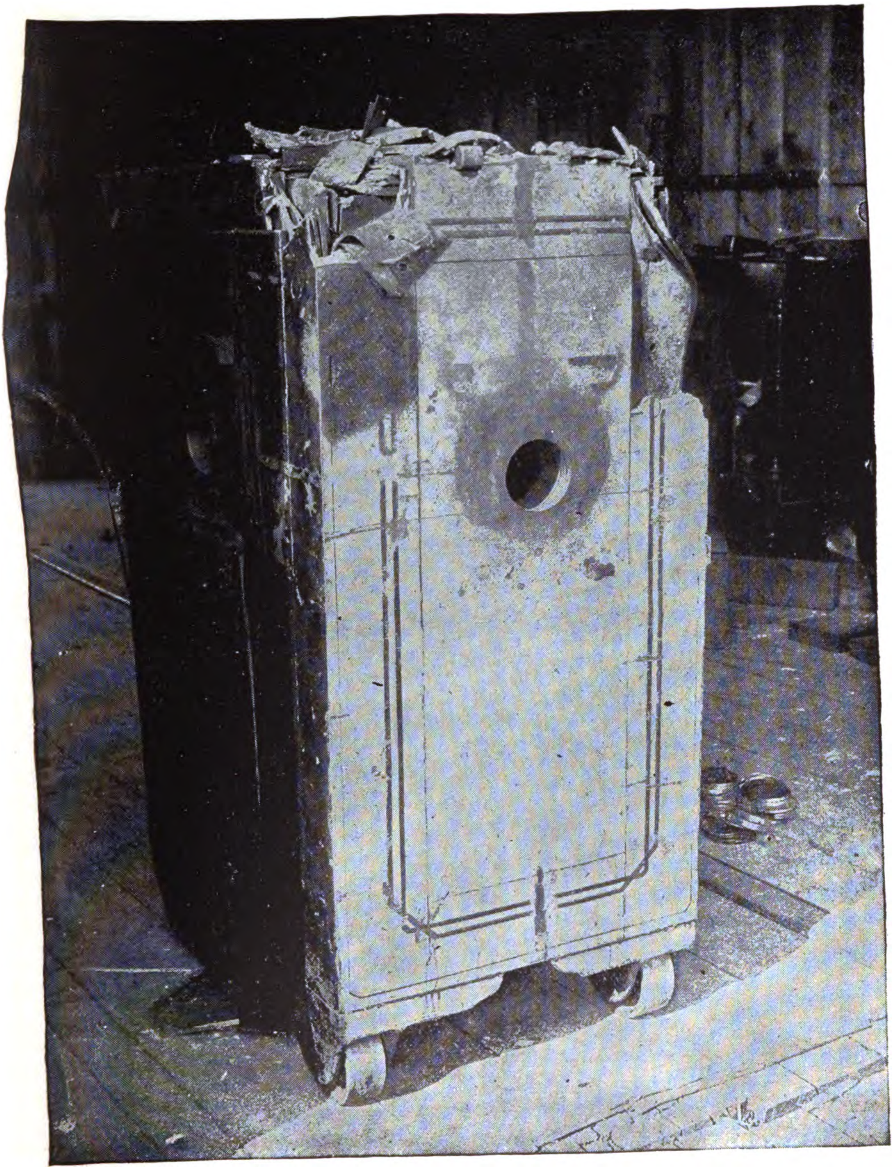
PHOTOGRAPH No. 25.



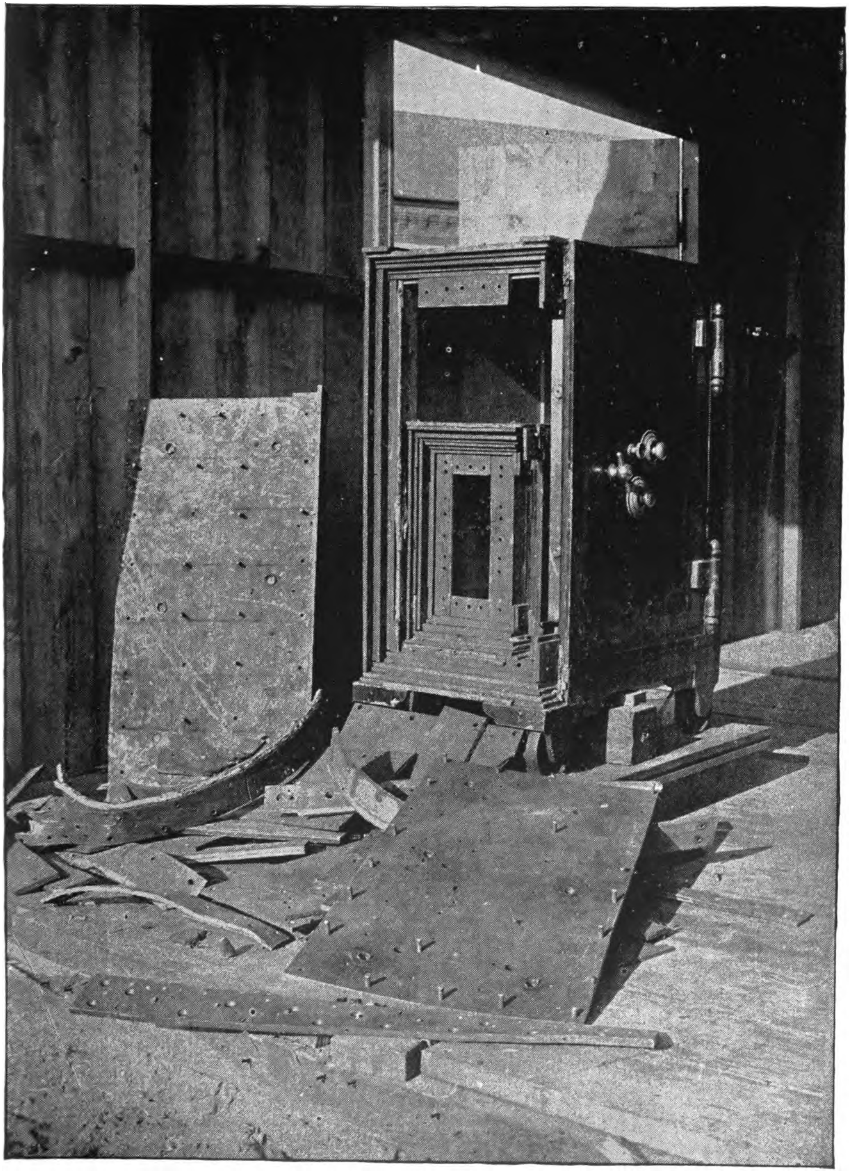
Photograph No. 26.



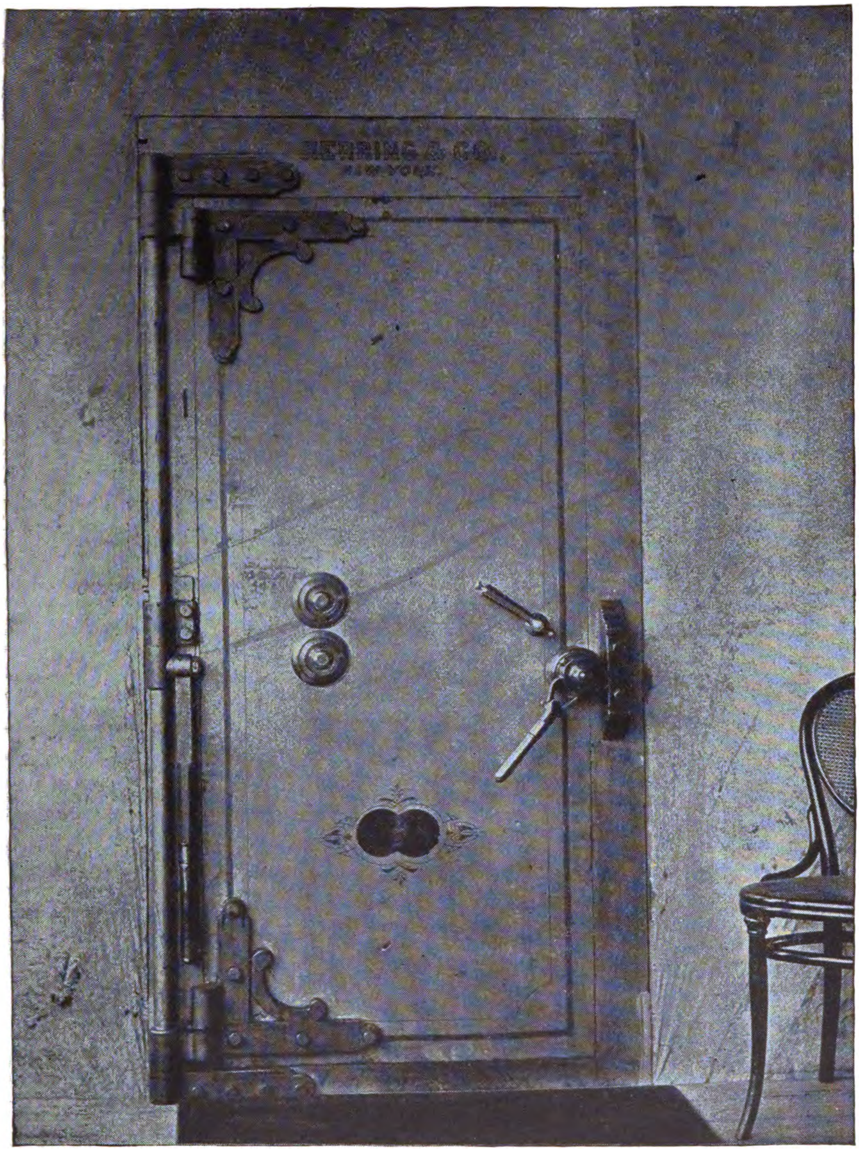
Photograph No. 27.



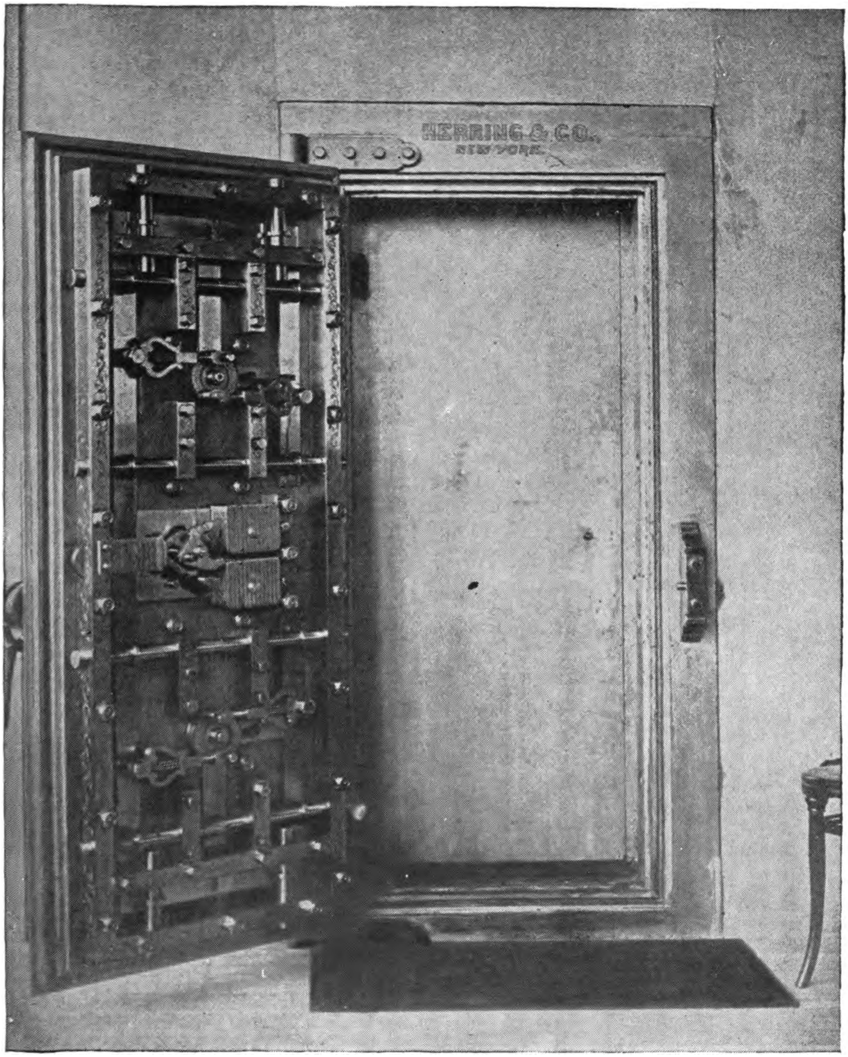
PHOTOGRAPH NO. 28.



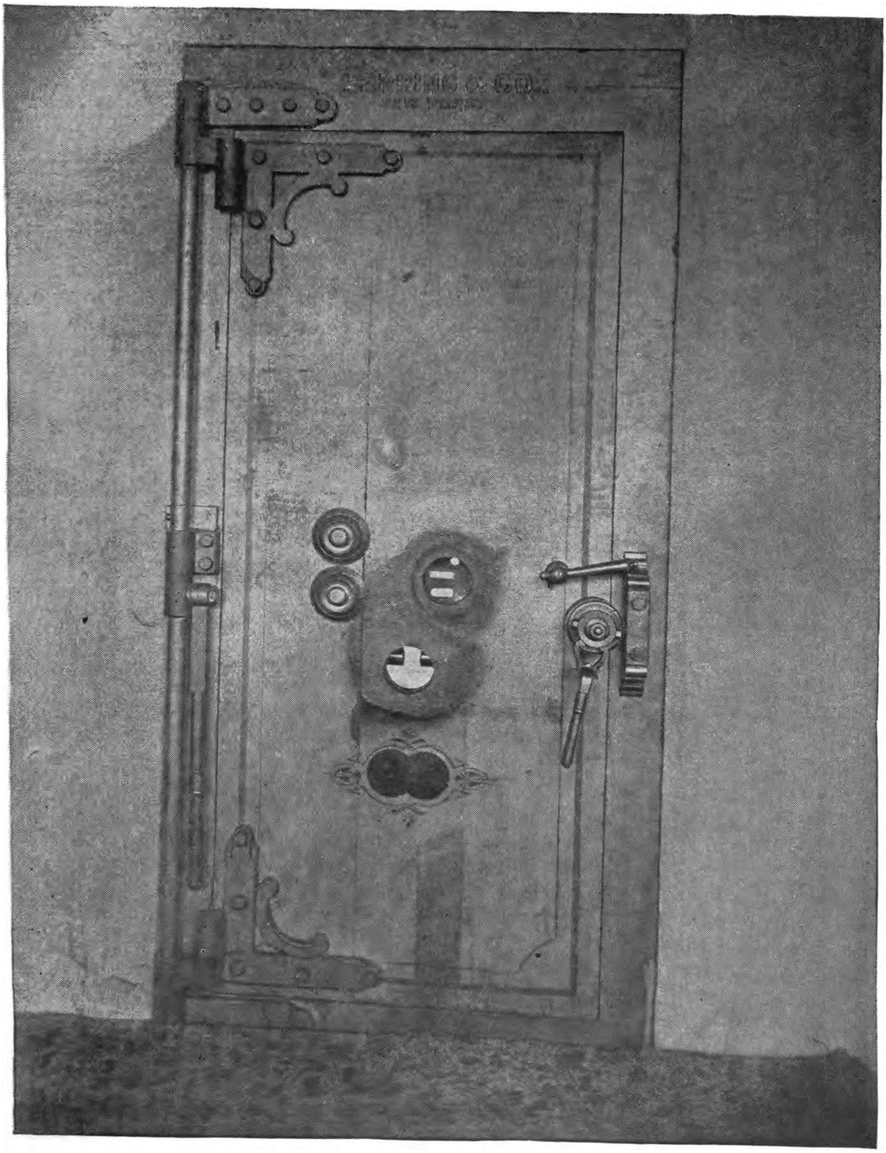
Photograph No. 29.



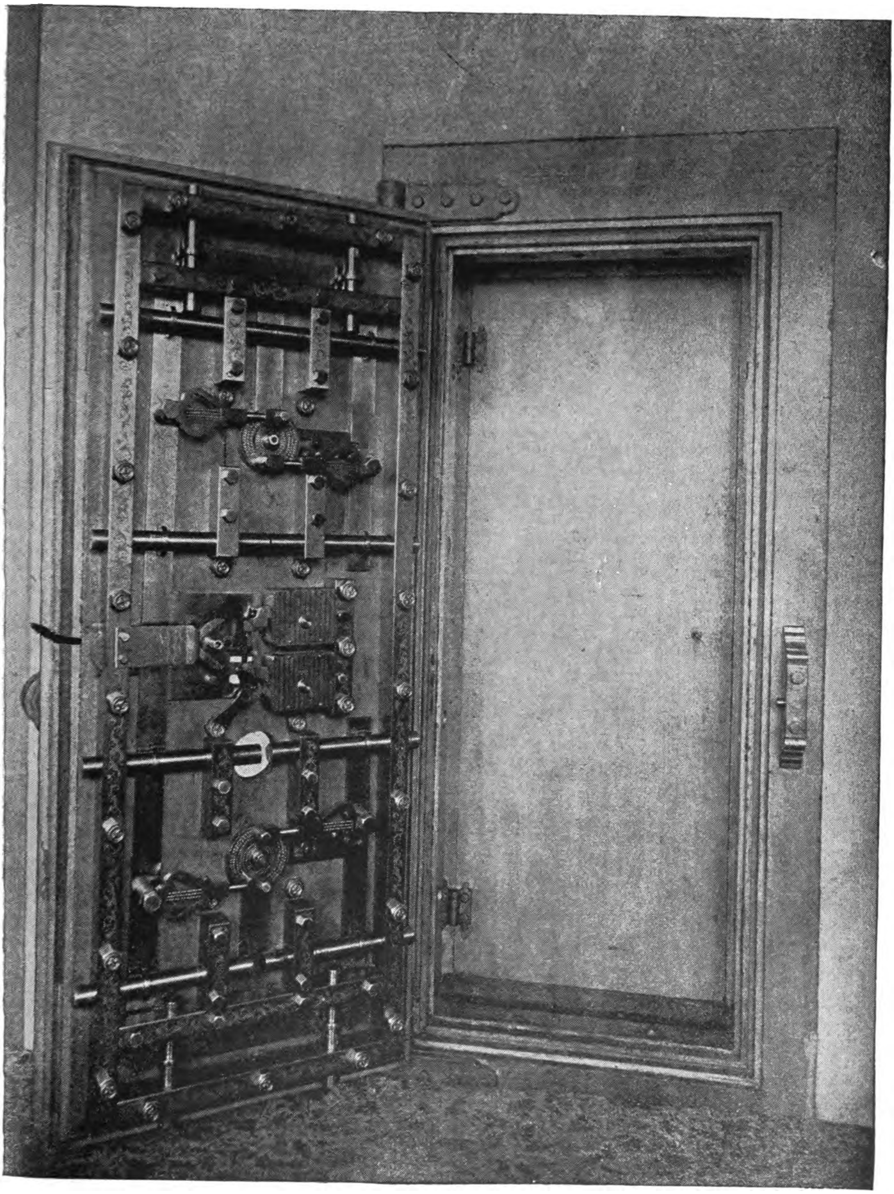
Photograph No. 30.



Photograph No. 31.



Photograph No. 32.



Photograph No. 33.

PHOTOGRAPHS 30, 31, 32, AND 33.

These represent a vault door taken from the Mercantile National Bank, New York City.

This door was locked and opened in the presence of four prominent gentlemen in two hours and eighteen minutes.

The second hole was subsequently made in the presence of two other prominent gentlemen in two hours and one minute.

RECORD OF DEMONSTRATIONS MADE IN THE PRESENCE OF THE TREASURY COMMISSION ON SAFE AND VAULT CONSTRUCTION AT THE WORKS OF THE CORLISS SAFE AND VAULT DOOR COMPANY, PROVIDENCE, R. I., DECEMBER 29 AND 30, 1891.

These minutes are made at the request of Chairman Thurston, by Lieut. Samuel Rodman, jr., U. S. A.

The object of these experiments was to determine by actual test the relative practical value of the laminated system of safe and vault construction and the Corliss system of construction.

EXPERIMENT No. 1.

At the time the commission was here, on their previous visit, one of its members suggested to Mr. Corliss that he would like to see a crucial test made of the Corliss safe, to determine whether or not it was possible to penetrate the safe by mechanical means by drilling a hole through the exterior shell and by drills and punches break away the steel rods contained in the lining, or displace the lining itself.

Anticipating the limited time at the disposal of the commission when they should arrive here, Mr. Corliss prepared a safe for this test by taking it apart and drilling a hole through the exterior shell previous to their arrival. This hole was seven-eighths of an inch in diameter and was drilled from the inside. The time required in drilling the hole was about a day and a quarter. The safe was then put together and mounted upon its base as for use. A substantial harness work was put about the safe so that the operation of drilling could be carried on with practically unlimited power for the feed. A staging was built about the safe so that the men could conveniently work the drills and handle the sledges to best advantage.

A number of very strong drills were made and a number of punches provided for making this test. Some of the punches were made with conical points and others with ends half rounded. They were tempered so as to afford the greatest possible strength against being battered and the greatest attainable rigidity to resist the blows of the sledge hammer.

Upon attempting to drill it was found impossible to make any headway whatever. The drills were broken as rapidly as put in, although every precaution was taken to apply the feed slowly to prevent any catching of the drill. After a number of attempts it was decided to keep the drill going, notwithstanding its edge was gone, simply to see what the effect would be. By this means we found that the drill was crowding to one side, and as we knew the result would soon be to strike another rod, which would effectually end the operation, we abandoned the attempt, concluding that it was impossible for the drill to penetrate or break the rods.

We then proceeded to try the punches and see if any impression could be made upon the rods by their use. Repeated attempts and careful measurements convinced the commission that no headway was being made in this direction, for the position of the safe was such as to make entirely effective the overhand blows of the sledges, and the fact was settled that it was impossible to penetrate the safe by this process.

EXPERIMENT No. 2.

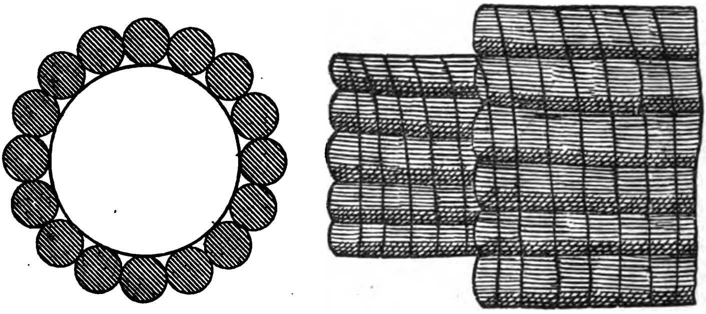
The extraordinary strength of the metal used in the Corliss safe and its remarkable resistance to blows, whether mechanically applied or applied by the use of high explosives, having been previously shown, by repeated tests, the following interesting experiment was made in the presence of the commission:

A back of a 36-inch Corliss safe was firmley embedded in the sand, the same being well packed up in the interior, in order to present as solid a backing as possible. On top of this was placed a 12½-pound cartridge of forcite powder No. 1, made up as shown in the accompanying figures.

First: View of the bottom of the cartridge, showing the can and the base of the cartridges.

Second: Elevation, showing general arrangement of the cartridge in firing position.

The detonator was placed in the top of the middle stick of the upper bundle. There was no tamping.



Result.—The only evidence left upon the surface to indicate that such a blow had been dealt, was a thorough cleaning off of the rust or sand upon the surface of the shell where the cartridge was placed and the development of a very fine hair crack about 6 inches long and of inappreciable depth.

EXPERIMENT No. 3.

Demonstrating the practicability of cutting a 4-inch hole through a square or laminated safe.

A Herring champion safe is represented in the accompanying photograph No. 1. It was built for the Mercantile National Bank, New York City, and was delivered at the works of the Corliss Safe and Vault Door Company, locked and sealed, in August, 1891.

From September, 1885, until it was removed to the works of the Corliss Safe and Vault Door Company in August, 1891, this safe was stored away in the cellar under the Mercantile National Bank, New York City; hence it remained there for six years, and during the whole of that time was neither unlocked nor opened. The safe was constructed as follows:

The first plate was of refined wrought iron, one-half inch thick, with solid angle edges and corners.

The second plate was of wrought iron, one-quarter inch thick.

The third plate was of horizontally-laid one-half inch 3 and 5 ply laminated welded steel and iron strips (presumably chrome), having turned corners, each plate being 6 inches wide.

The fourth plate was of franklinite, 1½ inches thick, cast on a double basket-work of one-quarter inch wrought iron rods. This plate was laid in sections, and had solid turned corners, cast of course.

The fifth plate was of wrought iron, one-quarter inch thick.

The sixth plate was of wrought iron, one-half inch thick.

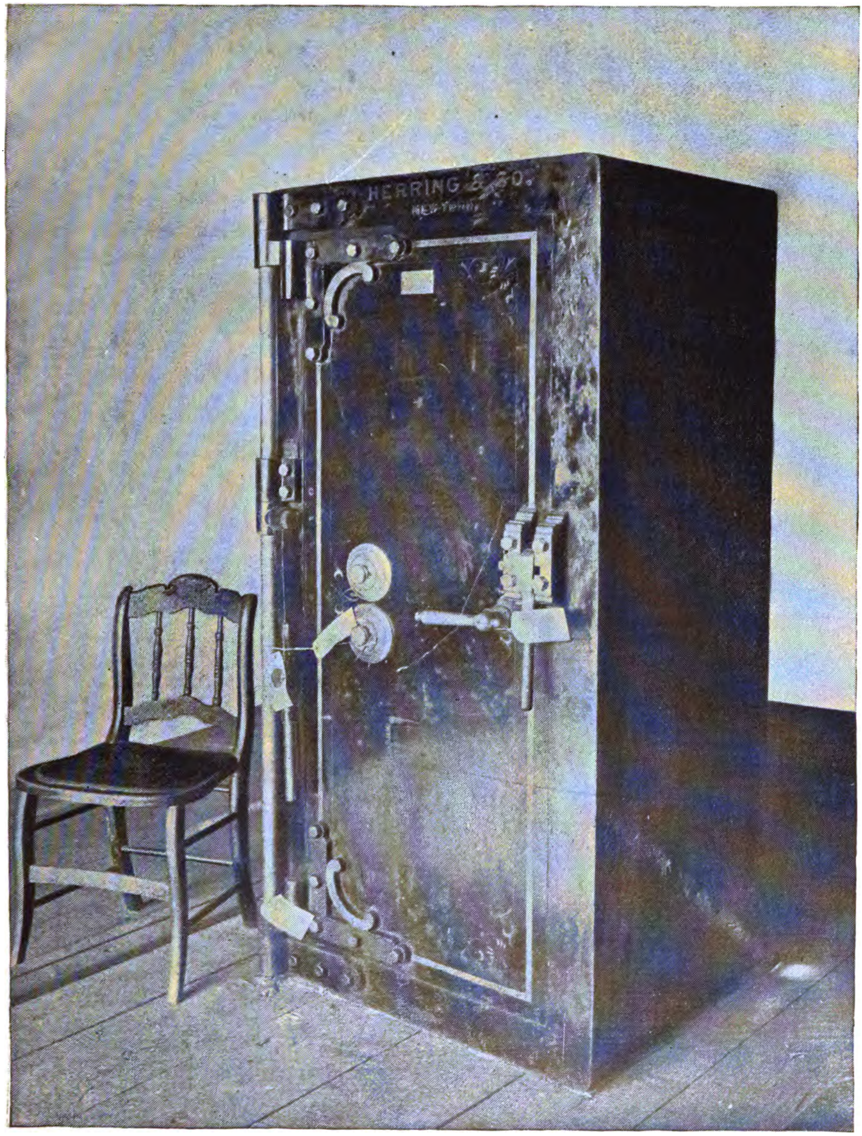
The outside measurements of the safe are as follows: Height, 5 feet 8 inches; width, 2 feet 8½ inches; depth, 2 feet 2 inches.

Inside, as was seen after the door of the safe was removed, the safe was divided into three equal compartments. The doors to each were one-fourth inch thick, wrought iron, and each was provided with a combination lock. The dividing walls of these compartments were also of wrought iron, one-fourth inch thick. The dimensions of the outside door are as follows:

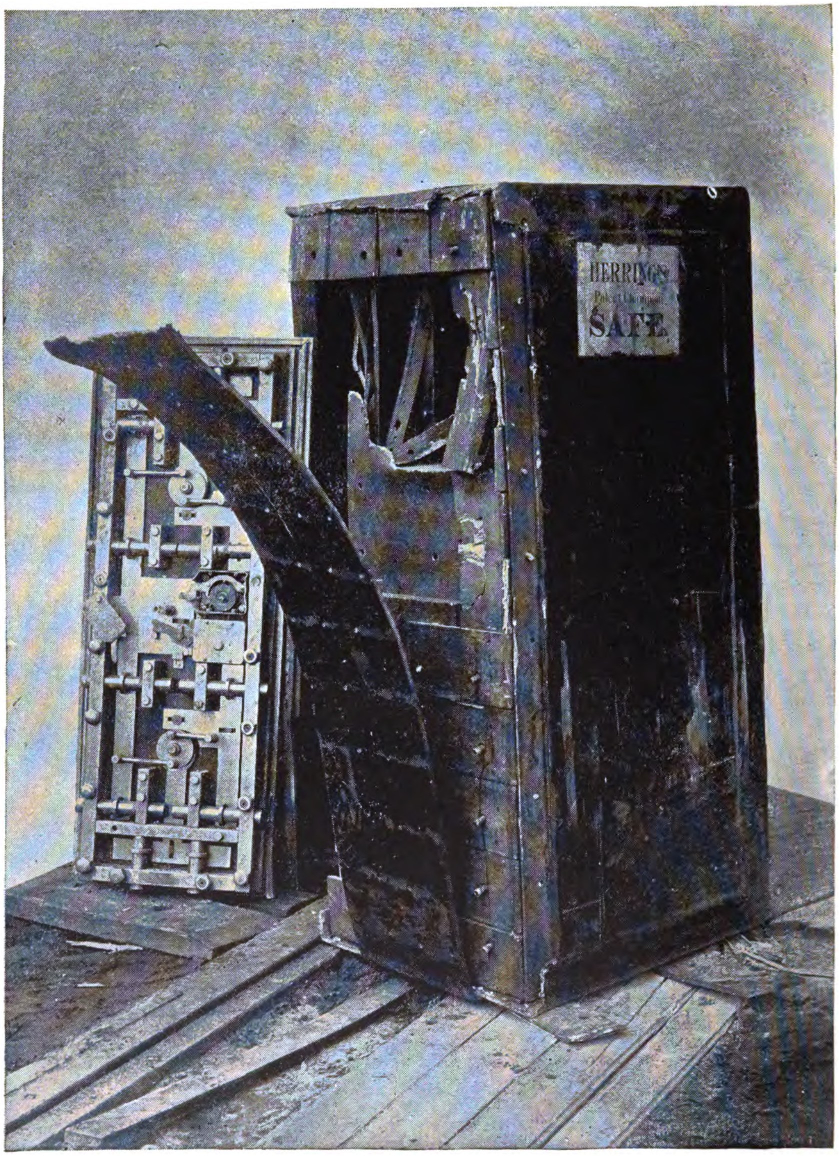
The outside door was 24 inches wide and 60 inches high, and we presume that it was constructed of the same materials and in a similar manner to the body of the safe. It was provided with tongue and groove, as will be seen by reference to photograph No. 2, and rubber packing. This door was a very fine specimen of laminated construction.

The plates of the safe were fastened together by numerous screw bolts varying from one-half to five-eighths inch in diameter.

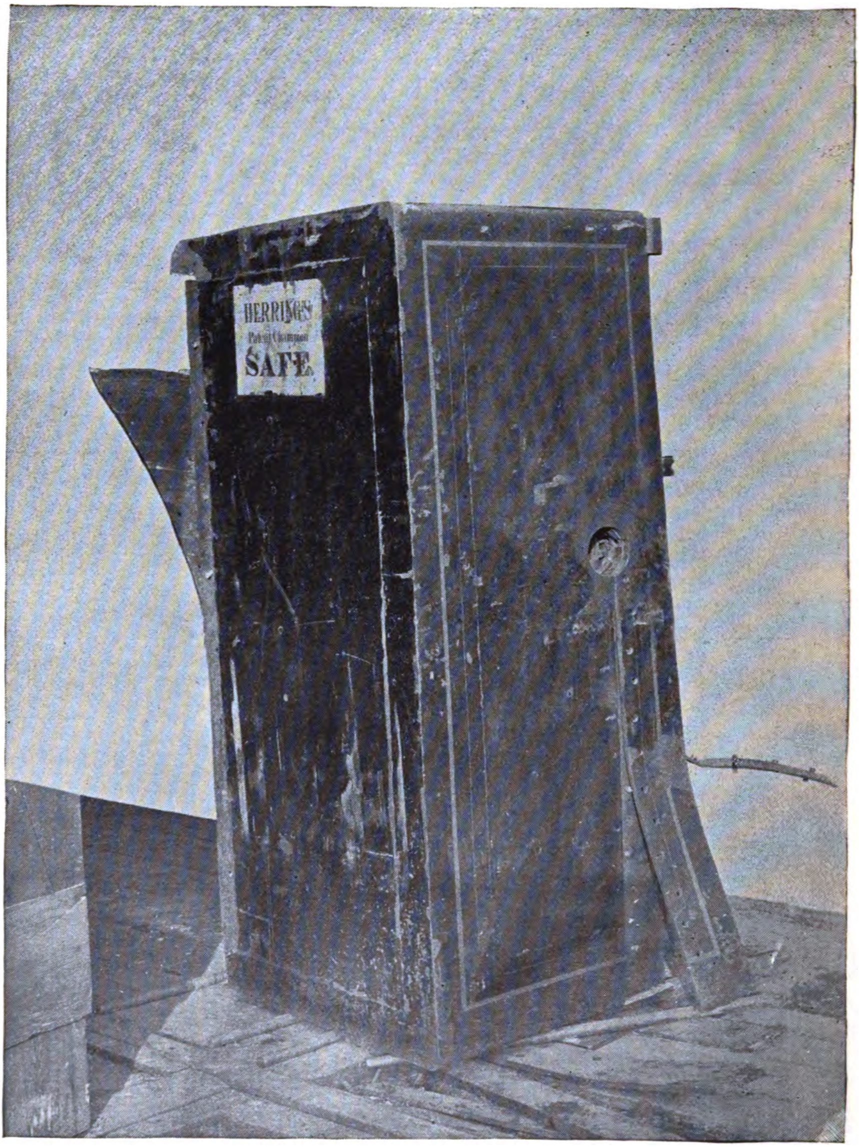
The wrought-iron framework which supported the bolts was fastened to the door by 20 seven-eighths inch screw bolts, which protruded through the frame and above it 1 inch, this part being threaded. On these were screwed nuts 1$\frac{7}{16}$ inches in diameter and 1 inch deep. The bolts which locked the door were 1½ inhes in diameter and their motion when the combination should be made was controlled by an eccentric, turned by a handle on the outside of the door. A pin fastened to what may be termed the sliding bolt plates, worked in this eccentric. Simple con-



PHOTOGRAPH NO. 1.



Photograph No. 2.

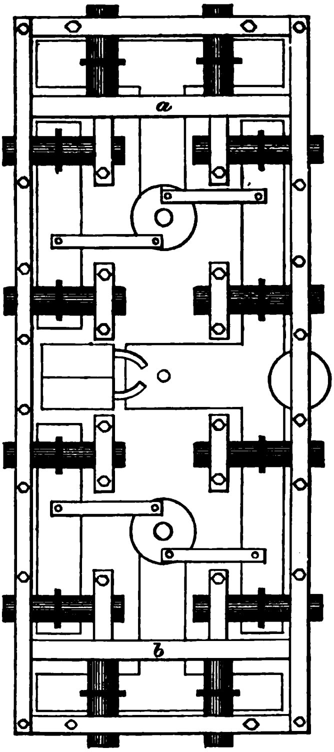


PHOTOGRAPH NO. 3.

nections between these sliding plates caused all to move when the one to which the pin was fastened did. There were twelve of these locking bolts, arranged as follows: two at the top, two at the bottom, and four on each side. The bolt frame measured $2\frac{5}{16}$ inches deep by $2\frac{1}{4}$ inches wide. There were two additional pieces, *a* and *b*, serving as a guide for the two upper and two lower locking bolts, of the same dimensions as the bolt frame. The side locking bolts were fastened at the middle to the sliding bolt plate. (See Fig.)

The description of the door as well as of the arrangement of the compartments inside the safe, is here given in order to convey a complete description of the entire construction, although it was not until after the safe had been opened that the constructions referred to were known. Photograph No. 2 shows this door.

The operation of cutting a 4-inch hole through the side was commenced at 12:58 p. m. (The position of the hole is shown in photograph No. 3.) The necessary rigging was put on the safe and the cutters began their work on the first plate at 1:08 p. m. At 1:20 this plate, wrought iron, was cut out. At 1:35 the second plate, wrought iron, was cut out. At 3:08 the third plate, welded steel and iron, was cut out. At 4:55 a 4-inch hole was cut clear through the franklinite $1\frac{1}{4}$-inch plate. At 5:10 the fifth plate, wrought iron, was cut out. At 5:30 the sixth plate, wrought iron, was cut out, thus completing the hole 4 inches in diameter entirely through the side of the safe. Time occupied in the whole operation, four hours and twenty-two minutes, a fraction less than 1 inch in depth per hour.



Work was then commenced upon removing the combination lock on the inside of outer door. The space in which to work was very small, there being only 3 inches of clear space between the inside of the outer door and the outside of compartment doors. The lock was, however, disconnected at 6.45 and in attempting to throw the bolts by the handle on the outside of the door, the spindle was wrenched off. Recourse was then had to a hook bent on the end of an iron rod to throw the bolts, by passing this hook round a three-fourths inch pin fastened to the center of the sliding bolt plate and pulling upon the rod. The pin referred to was the one against which which the combination lever pressed when the safe was locked and the combination thrown. It was virtually the center of motion of the whole locking system, and it appeared strange, considering the fact that the combination lock had been entirely disconnected, this should not, when the hooked rod was applied, have drawn the bolts back. The reason for this was subsequently discovered when the door had been opened, and it was that the locking bolts themselves had become so rusted that they could not be moved. This rust was the accumulation of six years, and it is needless to add that it would not have been present on the locking bolts of any safe in daily use.

Work was discontinued at 7:15. The time occupied in cutting a 4-inch hole through the body of this safe, as before stated, was four hours and twenty-two minutes. The time occupied in disconnecting the locks was about one hour, at which time the safe was virtually open, since, had the locking bolts not been rusted they could have been thrown by the handle which governs them, or had that broken, the hooked iron rod, pulling on the pin, fastened to the sliding bolt plate, would have thrown them. The balance of the intervening time (forty-five minutes) was wasted in endeavoring to move the bolts that were subsequently found to be rust-bound.

EXPERIMENT No. 4.

Demonstrating the practicability of entering a laminated safe by stripping off one entire side, plate by plate, using nothing but wedges, chisels, and sledges.

Before commencing this day's operations, the gentlemen of the Commission stated that they should be compelled to leave the works at 10:40 a. m. in order to connect with the 11:10 a. m. train for New York. It was therefore decided to proceed with the experiment of stripping the safe, plate by plate, with the understanding that work should be discontinued in time to enable them to witness certain tests with explosives which were under contemplation.

At 7:45 a. m. the operation of opening the Herring champion safe, before described, by tearing off one of its sides, was commenced.

The right hand side of the safe was attacked: the whole of the outside plate, as well as the solid angle corners at front and back, all of which were half an inch thick, was removed.

The second plate was similarly removed. The third course, composed of welded steel and iron, was nearly all removed, exposing the heavy plates of franklinite. At this juncture the hour of 9:40 had arrived, and after fracturing one of the heavy franklinite plates, work was discontinued in order to afford the Commission an opportunity to witness other experiments.

From the conditions in which the side of this safe was left after this attack of one hour and fifty-five minutes duration, it was evident to all that the complete removal of the side was a matter of a very short space of time, as practically nothing remained but the franklinite and a single plate of one-fourth inch iron.

EXPERIMENT No. 5.

This is in reality a continuation of experiment No. 1, in which the barred lining of the Corliss safe was proven to be sufficiently strong to resist penetration by any mechanical means that could be devised. Therefore, it was proposed to ascertain whether or not it was strong enough to resist explosive force.

To test this question, the 36-inch Corliss safe, recorded in experiment No. 1, was removed from the shop to an open lot and the seven-eighths inch hole was filled with 4 ounces of forcite power No. 1, a detonator imbedded in the mass, the charge covered with sand bags and fired.

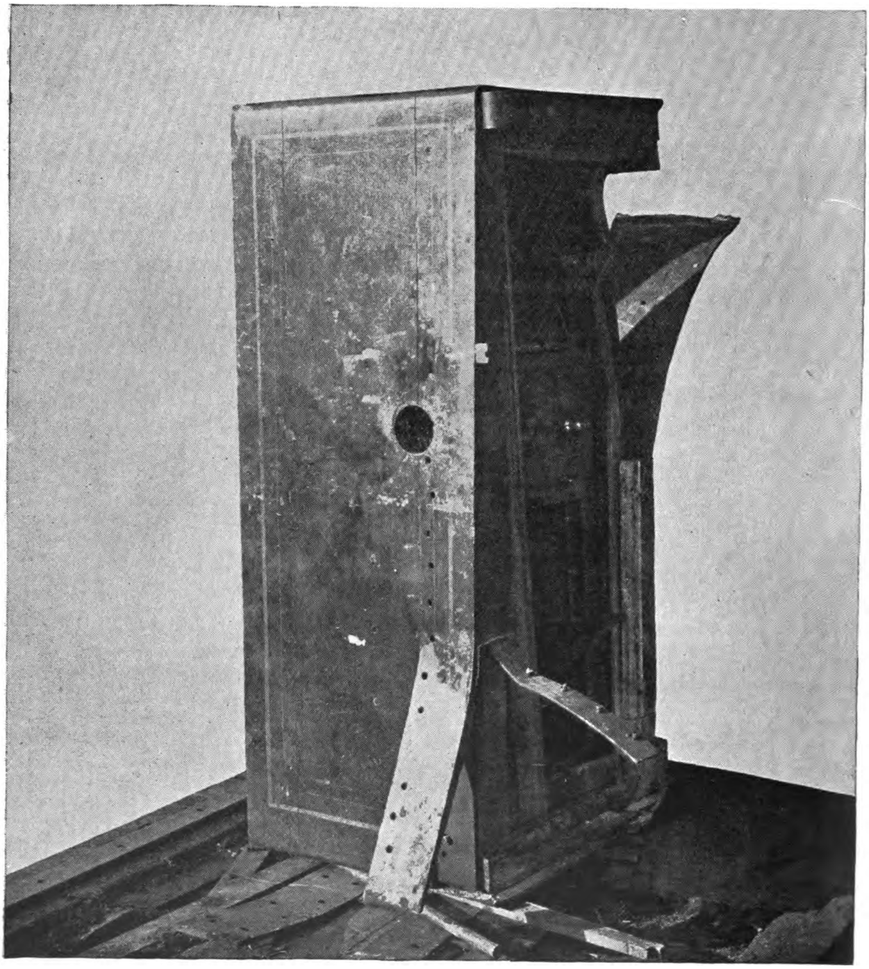
As the result of this explosion the surface of the back was very slightly spalled off around the hole and a few insignificant hair cracks of inappreciable depth were started. The lining was broken through and three bugs were blown out, only 2 of which could be found afterwards, one being broken by the explosion and the other knocked out whole. The hole in the lining was about 2 inches in diameter, but the seven-eighths inch hole in the shell was not enlarged.

The exterior shell of the safe suffered no injury. This experiment suggests the necessity of a stronger lining to support the bars, if provision against such a test is deemed necessary.

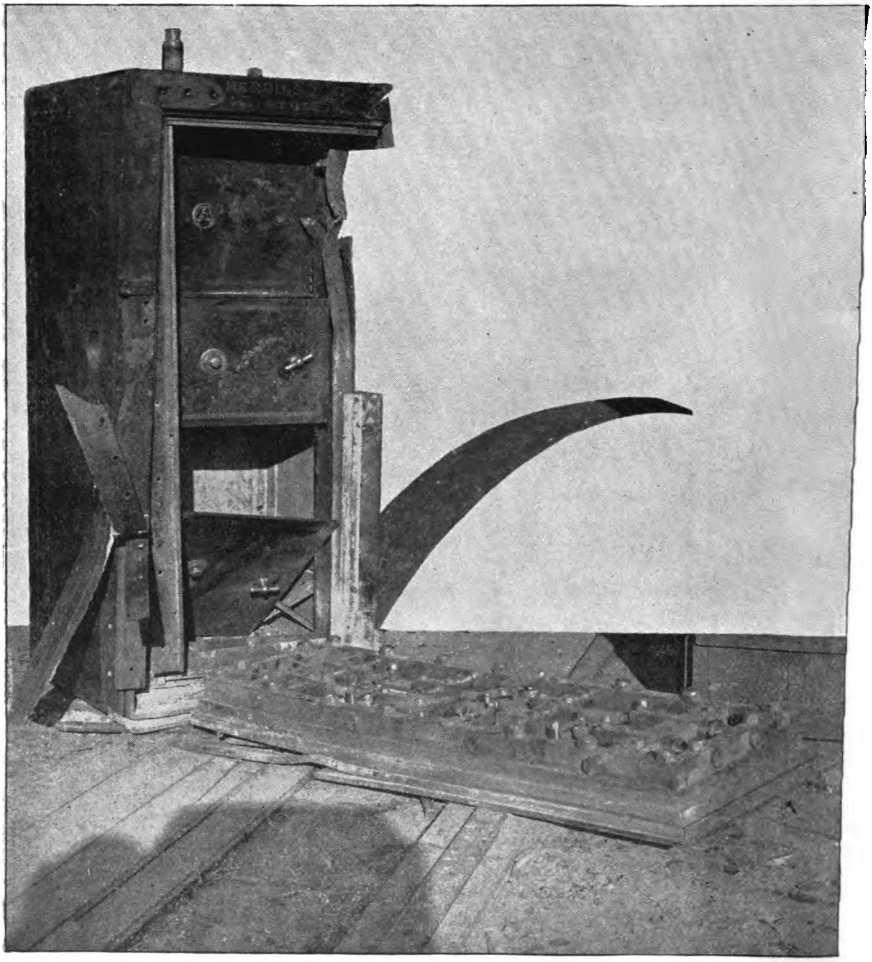
EXPERIMENT No. 6.

The following experiment was made to demonstrate the practicability of opening any rectangular laminated structure by the introduction of a very small amount of nitroglycerin into the joint between the door and the door-jamb.

At 10:15 a. m. the following operation was conducted on the door of the Herring safe, viz: The hinges were removed and the joint around the door from *a* to *b* to *c* was puttied. Had it not been for the fact that the outer jamb plate on the right of



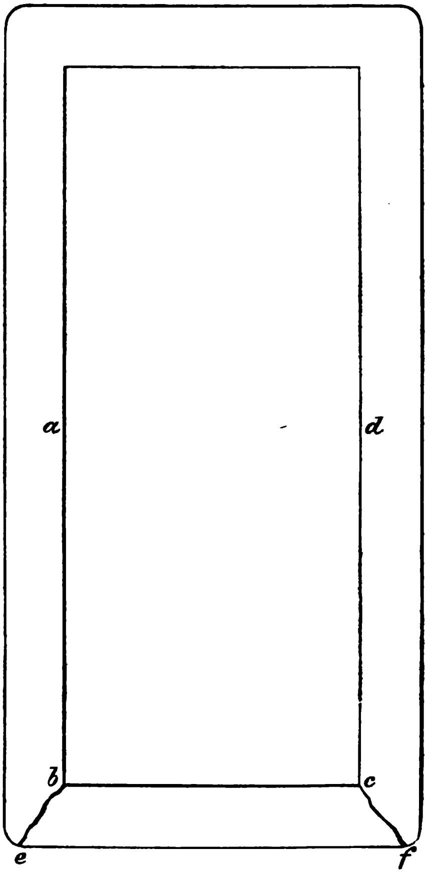
Photograph No. 4.



Photograph No. 5.

the door was removed in the operation of stripping off the side (Experiment No. 4) the crack from *c* to *d* would have been puttied also and the hinges would not have been removed.

A well of putty was made at *a*, and into this were poured 4.8 ounces of nitroglycerin. This ran rapidly into the crack, notwithstanding the fact that the fit of the door was very close—much closer, indeed, than ordinarily prevails, even in first-class work of this kind. No wedges were used to widen it. At the end of about six minutes nitroglycerin was seen running out at *c*, so putty was placed at this point and a short distance up from *c* along the crack *c d*. A detonator was now placed in the well at *a*, and at 10:23, just eight minutes after commencing the operation, the charge was fired.



As the result of this explosion the whole of the jamb below the door was blown out—that is, the portion marked *b c f e* in the figure—and right under the door, on the left-hand side, at *b* was a space large enough to admit the hand and arm.

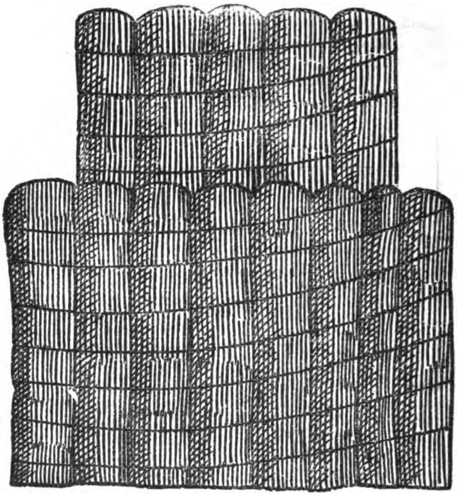
The plate of franklinite was literally shattered into fragments. It was discovered afterward that the effect on the interior of the safe from this explosion was as follows: The door of the lower compartment was blown in and the dividing shelf between the lower and middle compartment was blown upward and then fell back to the bottom of the safe. The first three plates of the jamb on the left of the door were torn out at the lower portion down to the franklinite, and the first plate of the door $\frac{3}{16}$ inches thick, was entirely stripped off.

Photographs Nos. 4 and 5 show the effect of the explosion on the jamb under the door and on the jamb-plates on the lower left side of door.

EXPERIMENT No. 7.

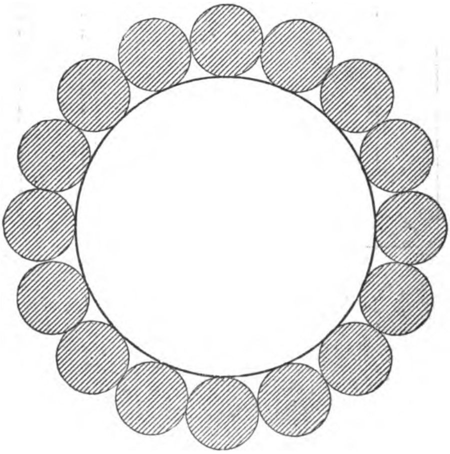
This experiment was made in order to prove by actual demonstration, before the commission, the inherent weakness of all laminated safes and vaults when attacked by high explosives, such as may be made use of in case mob rule prevails.

At 10:25 a. m. a 9½-pound cartridge of forcite powder No. 1 was placed on top of the screw door safe described in experiment No. 20 of my report.



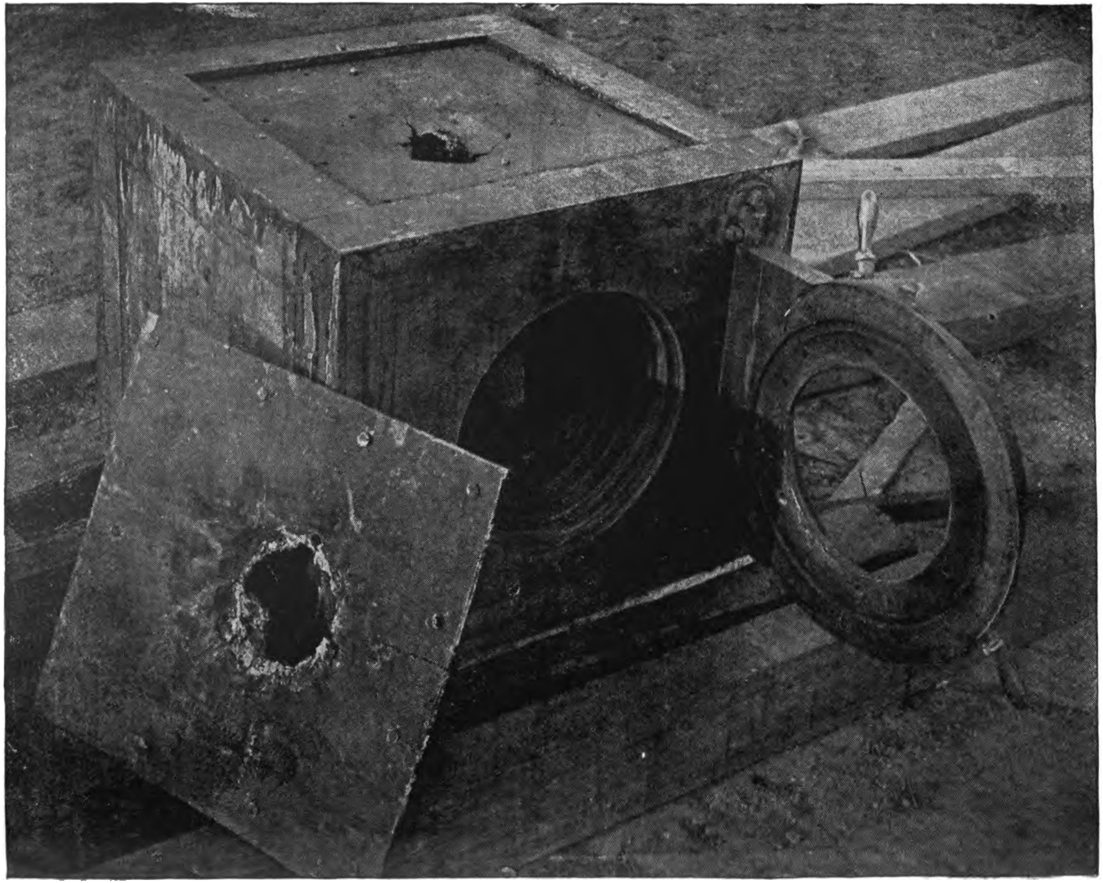
This cartridge was made up exactly as the one described in experiment No. 33, of said report. The detonator was placed in the top of the middle stick of the upper bundle, and fired. There was no tamping.

As the result of this explosion a hole 3 inches in diameter was made clear through to the interior of the safe, through a series of wrought iron and laminated plates, built up to a thickness of 4¾ inches. Around the edges of the opening produced by the explosion could be seen the fused iron and steel, a result developed by the high heat of the gases of explosion.

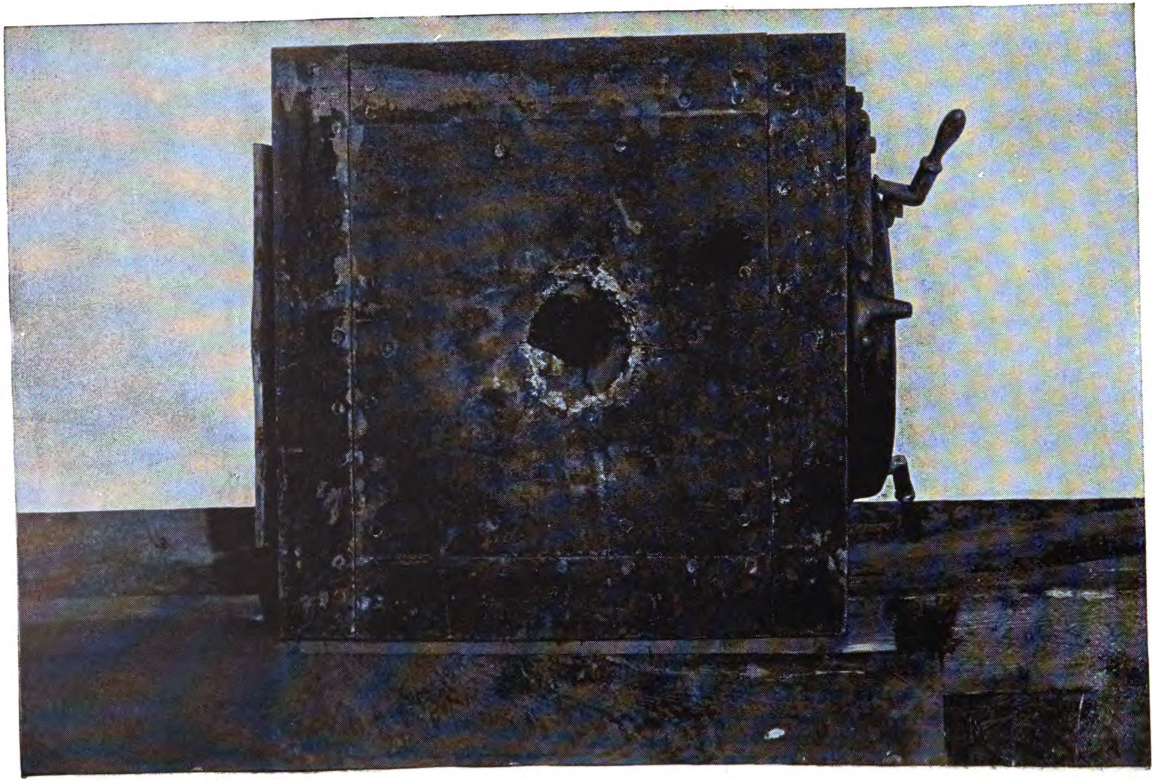


A bucket of water was now brought and poured over the top of the safe to cool the plates, and another cartridge of forcite powder No. 1 was made up similar to the first used, but weighing 12½ pounds, and was placed can down with its center right over the center of the 3-inch hole just made. The base and elevation of this cartridge are shown in the accompanying figures.

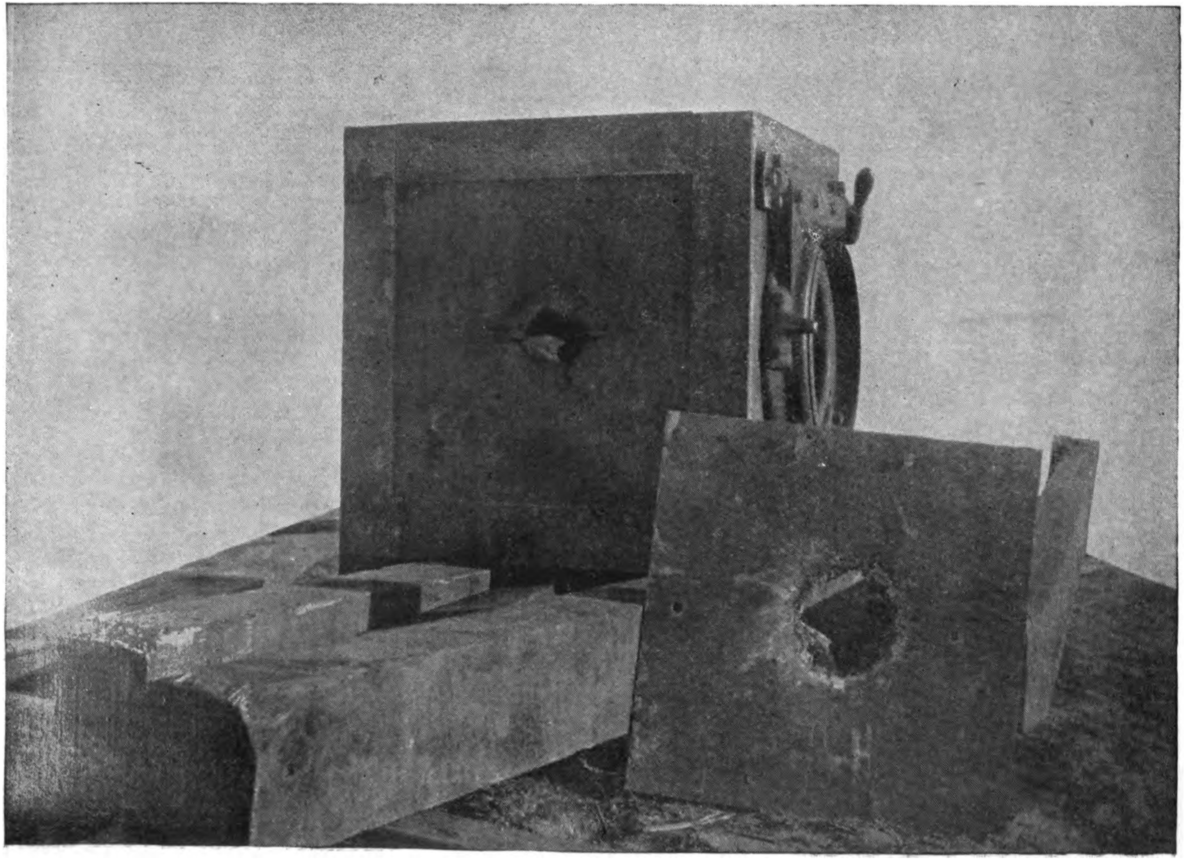
The detonator was imbedded in the top of the middle stick of the upper bundle and fired. No tamping was used.



Photograph No. 6.



Photograph No. 7,



Photograph No. 8.

The result of this explosion was to increase the diameter of the hole already made to 5½ inches in the first plate and a clear diameter of 4 inches in all the underlying plates right through to the interior of the safe. The first plate of wrought iron rebounded from the top of the safe about 20 feet into the air and fell within a few feet of the safe.

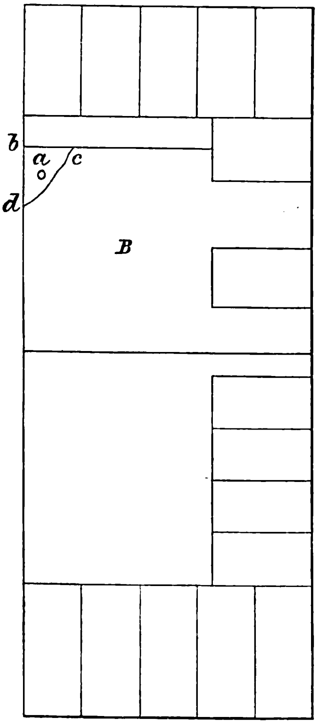
The second cartridge was fired at 10:32 a. m., making the total time occupied by both operations seven minutes.

The disastrous effect of such explosions upon laminated constructions is made forcibly apparent when we consider the unusual strength of the safe experimented upon, for this safe was practically a cube 29 inches by 29 inches and 4¾ inches thick. The size of hole that would have been produced had the area of the side been as great as that of a safe deposit vault, can more easily be imagined than determined. (See photographs Nos. 6, 7 and 8.)

The commission left immediately after the firing of the last-mentioned charge. Mr. Corliss accompanied them.

Mr. Clark and the undersigned resumed experiments on the Herring safe and completely demolished it in a few minutes time, as will be seen by the following record of the proceedings.

At 11 a. m. a small hole was punched through the upper left hand corner of the plate of franklinite B. on the right-hand side of the safe and at the point marked *a*. (See Fig.)



The strips on the top and right side are the welded steel and iron plates which had not been removed in the operation of stripping off this side of the safe.

One-quarter of an ounce of forcite powder No. 1 was inserted in this hole, a detonator imbedded in it, and at 11 a. m. the corner of the franklinite plate was torn out.

The portion is included in the lines *b, c, d* in the figure. Behind this plate was a half-inch wrought iron plate, and between it and the franklinite was a space of one-fifth of an inch. Into this space was packed four ounces of forcite powder No, 1, which was pushed well down behind the franklinite, a detonator imbedded in the charge and fired.

As the result of this explosion the whole plate of franklinite B, was blown out, the entire door of the safe was also blown out bodily, and fell to the front exactly as shown in photographs No. 9 and 10.

The side wall of the upper compartment was also blown in.

The several operations performed upon this safe may be recapitulated as follows:

First, cutting a hole 4 inches in diameter entirely through side wall, which was 4 inches thick.

Second, stripping off the greater part of one side of the safe, work upon which was discontinued, as before stated, in order to afford the commission time to witness the experiments with explosives.

Third, blowing away the jamb of the door by introducing nitroglycerin in the joint.

Finally, completely wrecking the safe by using explosives applied underneath the plates. This last operation was really a surprise to us all, for we had expected only to remove a small section. The plates were so loosely held that we did not expect much confinement of the blow. Had the commission remained twenty minutes longer they could have witnessed the whole operation.

Upon reporting the matter to Mr. Corliss we learned that it had been his intention to resume the stripping operation and continue it until the whole side of the safe was removed, which certainly would have been accomplished in less than an hour's time.

It may be of interest to add here a brief description of the method of obtaining nitroglycerin. This substance is dangerous to manufacture, difficult to buy, but easy to obtain by extracting it from the ordinary commercial dynamite.

Dynamite is a name given to explosive compounds wherein nitroglycerin is the active agent, and the body of the compound is simply a vehicle for safe storage and transportation. Otherwise speaking, in all commercial dynamites, nitroglycerin is an active element.

The process of extracting it is as follows:

Take a cartridge of dynamite and break it up into small pieces; put these into a bottle of convenient size and pour over them a quantity of 95 per cent alcohol; shake the bottle freely and by means of a wooden stick break up the soaking dynamite into as small particles as possible. The alcohol cuts the nitroglycerin and changes its color to a light yellow. The pulp, as the mixture of alcohol and dynamite may be termed, is now filtered in another bottle, the residue is squeezed out, and the liquid from it also filtered. Small portions of this filtered alcoholic solution are now poured into a small bottle, and about as much water as there is solution is added. The mixture now becomes milk white. Shake the bottle for a few moments when the water will dilute the alcohol and precipitate the nitroglycerin so that upon standing it settles to the bottom of the bottle. Pour off the water and alcohol and then pour the nitroglycerin into the receptacle provided for it.

Samuel Rodman, Jr.,
First Lieutenant, Second U. S. Artillery.

The following series of experiments have been made at the suggestion of Mr. Ely for the purpose of ascertaining by actual test whether or not it is practical:

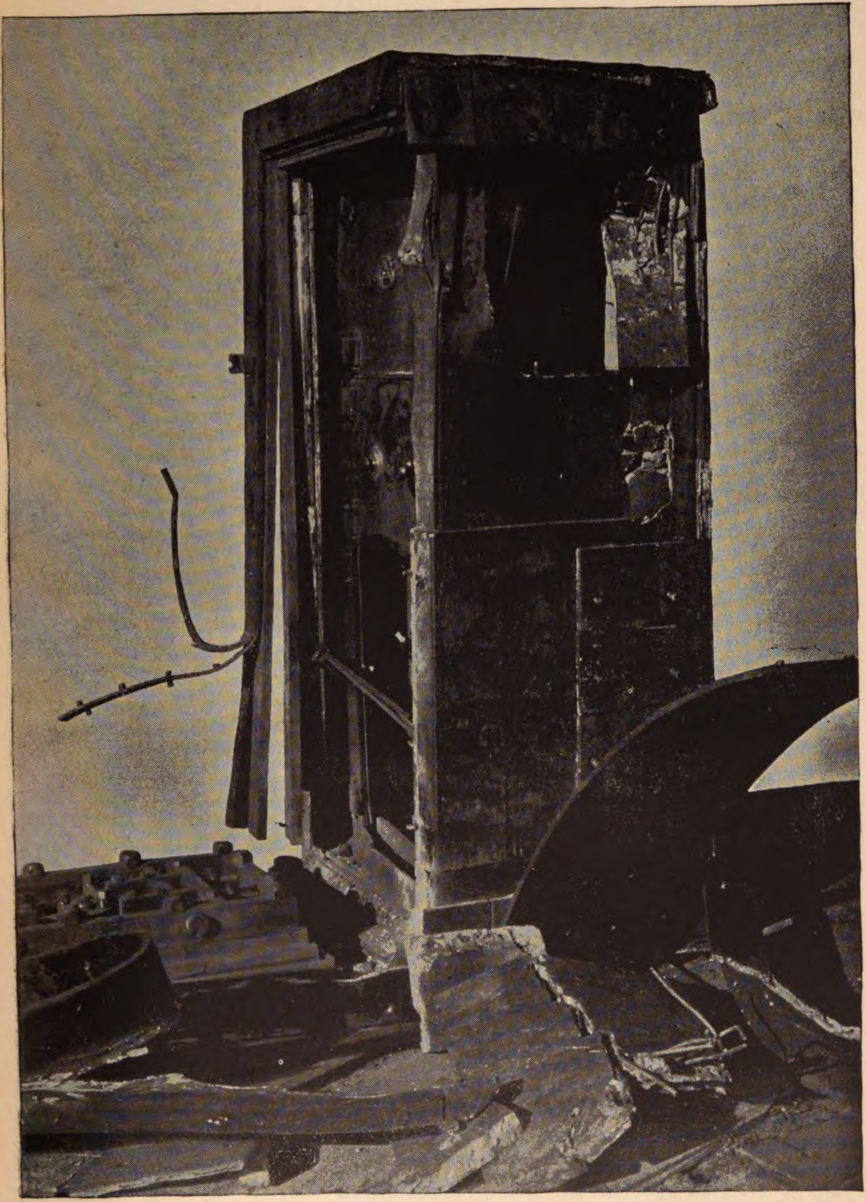
First, to introduce fluid nitroglycerin into or through the joint between the door and door jamb of a Corliss safe in its normal condition.

Second, supposing it to be impossible, by reason of the closeness of the joint, to introduce nitroglycerin, is it possible, by means of a "battering-ram" or by "mechanical pressure," or by "explosives," to force the door inward sufficient to effect such introduction, notwithstanding the expanding ring?

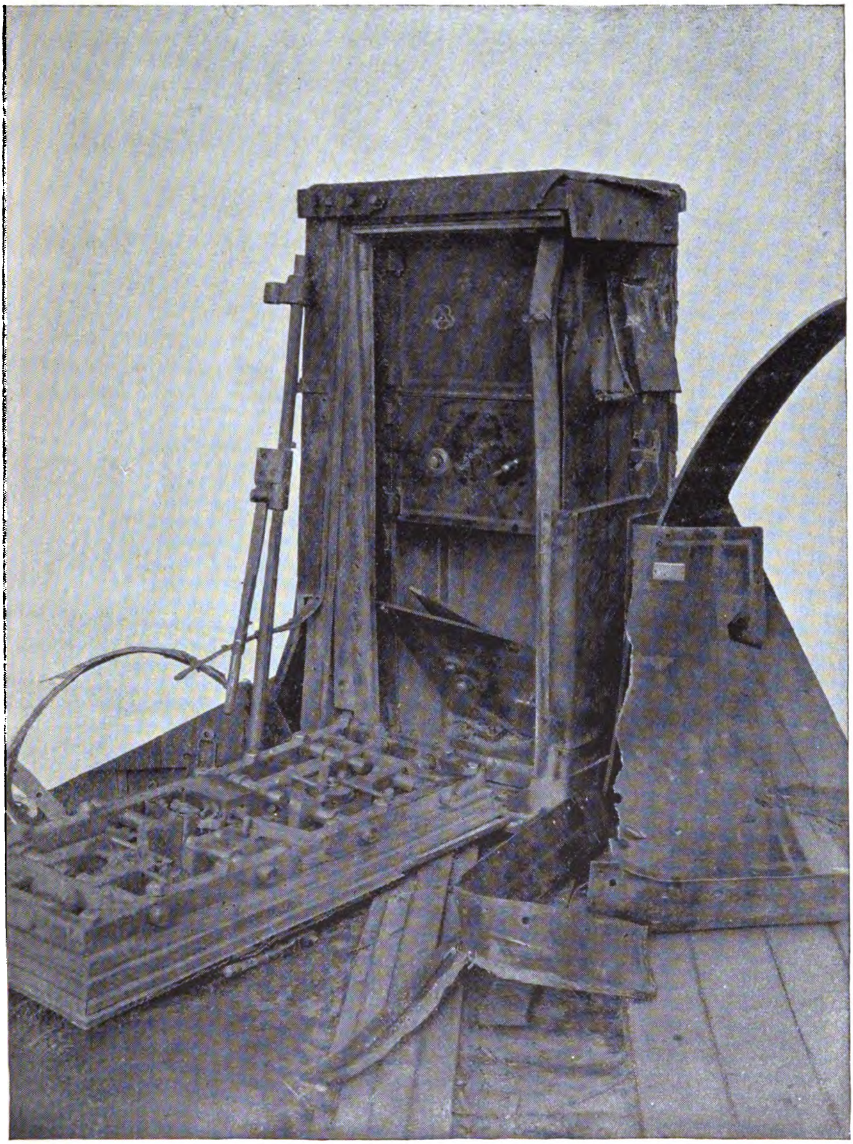
Third, if it is found possible by either of the above processes to effect an opening of the joint sufficient for the introduction of nitroglycerin, would the firing of such a charge result in the destruction or disintegration of the door jamb, as in the case of the laminated construction, or would the mass of metal at this point be sufficiently strong to withstand such an explosion?

EXPERIMENTS OF JANUARY 14 AND 16, 1892.

The object of these experiments was to determine the practicability of introducing a charge of nitroglycerin between the door and jamb of the Corliss safe, and if this should prove to be a practicable operation, to determine what effect, if any, the explosion of the introduced charge would have upon the door or door jamb.



PHOTOGRAPH No. 9.

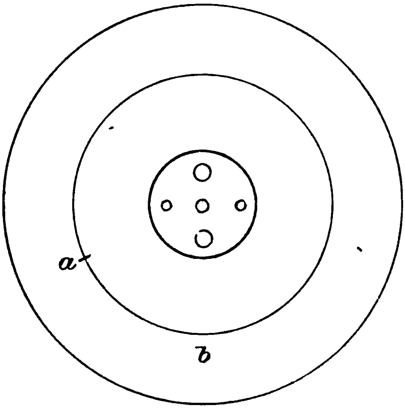


Photograph No. 10.

EXPERIMENT No. 1.

A regular front and door of a 36-inch Corliss safe was set up in its natural position, *i. e.*, the door vertical. The door and front both had the ordinary machine-turned fit, *but not ground*. The door was screwed into its closed position in the front and the ring expanded. At the point *a* in the figure, where the charge was introduced, the crack between the door and jamb was 25-10000 inch open, so to speak.

At this point *a*, a well of putty was made and into it were poured one-third ounce of nitroglycerin.



At the end of fifteen minutes after pouring the nitroglycerin into the well, about one-fourth ounce had run in through the crack between the door and jamb.

A detonator was now placed in the well at *a* and the charge fired.

After the explosion the door was set back and turned around in order to determine what had been the effect of this introduced charge.

The nitroglycerin had run down on the inner part of the outer step of the jamb to the bottom or lowest point, and then had run back over the inner steps and down between the bugged lining and the shell.

All of this was deducible from the fact that the outer step of the jamb presented a blackened appearance from the point *a* down to point *b*, and that some of the soft metal back of *b* was chipped off.

Apart from the blackened appearance of the first step of the jamb, which was also to be noted on the first step of the door, no effect whatever was produced either upon the door or the jamb.

This experiment demonstrates very conclusively that not enough nitroglycerin can be introduced between the door and jamb of the Corliss safe, even where the fit results from ordinary machine turning, to produce any effect whatever upon the door or door jamb.

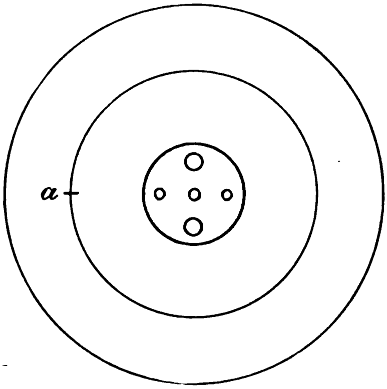
Regardless of the quantity of nitroglycerin poured in, there is always the same definite amount which will remain between the door and door jamb, and any more than this definite amount will run back into the safe and be negative so far as any effect to be produced upon the door jamb until such a large quantity has been introduced that its explosion will completely demolish the safe. This, however, exceeds the limits of practicability in the Corliss construction.

In the laminated system of construction, the case is different and the practicability of destroying the jamb of such a door by the introduction of a small charge of nitroglycerin between the door and jamb has already been demonstrated to be an entirely successful operation.

EXPERIMENT NO. 2.

A regular front and door of a 36-inch Corliss safe was set up in its natural position, *i. e.*, vertical. This front and door had a ground fit, *i. e.*, the first step of the door and that of the jamb fitted each other absolutely tight throughout their entire width and circumference.

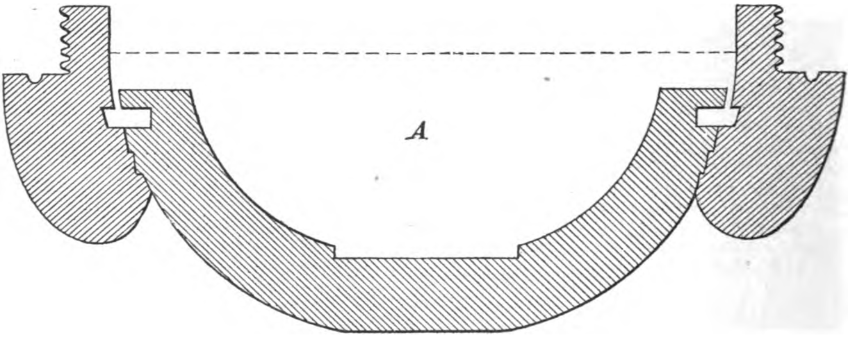
The door was screwed into its closed position in the front and the ring expanded.



A deep well of putty was made at *a* and into it was poured one-half ounce of nitroglycerin. This was allowed to stand for twenty minutes, being carefully watched from time to time in order to see if there were any indications of the nitroglycerin running into the joint. The pool remained at a constant depth, however, and at the end of twenty minutes the nitroglycerin was run back into the one-half ounce measure from which it had been poured, and it was found that it filled the measure, a proof that none had run into the joint.

The door was set back and swung around and the outer step of door and jam carefully examined. Not a trace of nitroglycerin was to be found upon either.

Some days previous to this experiment this front was laid down in a horizontal position and the door lowered into its place, as shown in the sectional figure.



Water was poured into A to a depth indicated by the dotted horizontal line, and allowed to stand three-fourths hour. The fit of the door and jamb was found by this test to be so tight that no water ran into or leaked out from the joint.

The conclusions reached from these experiments can not be overestimated, for it is thereby proven beyond question that neither liquid explosive nor water can be introduced into the ground joint between the door and the jamb of the Corliss safe.

EXPERIMENT No. 3.

This experiment was conducted upon the same front and door as was used in the preceding experiment.

It was found that in its closed position, the ring being expanded, the upper part of the door could be set back very slightly by turning back the upper spindle. This was accordingly done, and at the point *b* the point was found to be about 20-10000 inch open. This opening extended from *c* to *b* to *d*, while from *c* to *e* to *d* the fit was still absolutely close. (See fig. below.)

A well of putty was made at *f* and into this were poured one-quarter ounce of nitroglycerin.

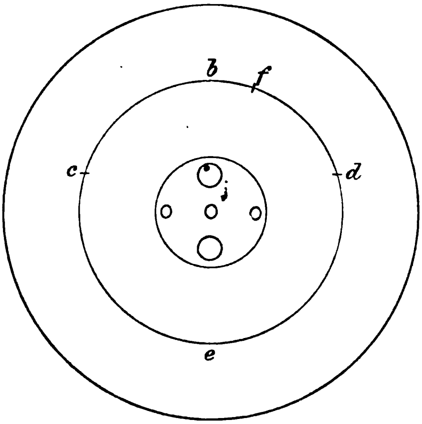
This was allowed to remain for fifteen minutes, and then all but a few drops was run back into the measure from which it had been taken. From a careful comparison of the amount collected in the measure with what remained in the well of putty it was ascertained that not more than three or four drops of nitroglycerin had run in through the crack at *f* during the entire fifteen minutes. It also appeared that no more would run in, because, after settling a trifle during the first five minutes, the liquid remained at a constant depth until the end of the fifteen minutes.

A detonator was placed in the well at *f* and the charge fired.

The door was then set back, turned around and the steps of both door and jamb carefully examined.

There was no effect whatever produced upon the door or jamb, and the only trace existing to show that any nitroglycerin had run in was a black deposit from the gases of explosion on the outer step of the door and jamb extending from *f* to *d*.

It is fair to assume that the nitroglycerin did not cover this space, because not enough ran in to do so, but that the gases of explosion penetrated through this small crevice and left their trail on the outer step.



The joint at the point *f* was about 15-10000 inch open, and I conclude that this space is too small to allow the flow of nitroglycerin through it.

It must be borne in mind that in the regular locking mechanism of the Corliss safe the upper and lower spindles are locked after the door has been screwed up and the ring expanded. This precludes the possibility of turning back the upper spindle, as was done in this case by way of experiment.

From these experiments the conclusion must be reached that in the ground-fitted door of the Corliss safe there is no possibility of introducing any explosives in the joint between the door and the jamb.

Samuel Rodman, Jr.,
First Lieutenant, Second U. S. Artillery.

EXPERIMENTS JANUARY 27 AND 28, 1892.

The object of these experiments was to ascertain if the explosion of a mass of dynamite or other similar high explosive upon the door of a Corliss safe would drive it inward, so as to make an appreciable opening between the door and the door-jamb, notwithstanding the expanding ring.

The safe operated upon is shown in Fig. A-1, which represents its actual position during these experiments.

The door was screwed to its closed position and the ring expanded. All the spindles had been removed from the door. In order that the effect of the charges used should be transmitted as evenly as possible over the entire door, and to prevent, as far as could be done, the escape of the gases of explosion through the spindle holes, a half-inch wrought iron plate was bolted over the plane surface or center of the door.

This door had been used in some previously conducted spindle experiments, and had been considerably cracked, as shown in Fig. A-1.

For the purpose of these experiments there were made up ten cylindrical charges of forcite powder No. 1, as follows:

	Ounces
No. 1. One stick	8
No. 2. Two sticks	16
No. 3. Three sticks	24
No. 4. Four sticks	32
No. 5. Five sticks	40
No. 6. Six sticks	48
No. 7. Seven sticks	56
No. 8. Eight sticks	64
No. 9. Nine sticks	72
No. 10. Ten sticks	80

The total amount of forcite powder No. 1 was 440 ounces, or 27½ pounds.

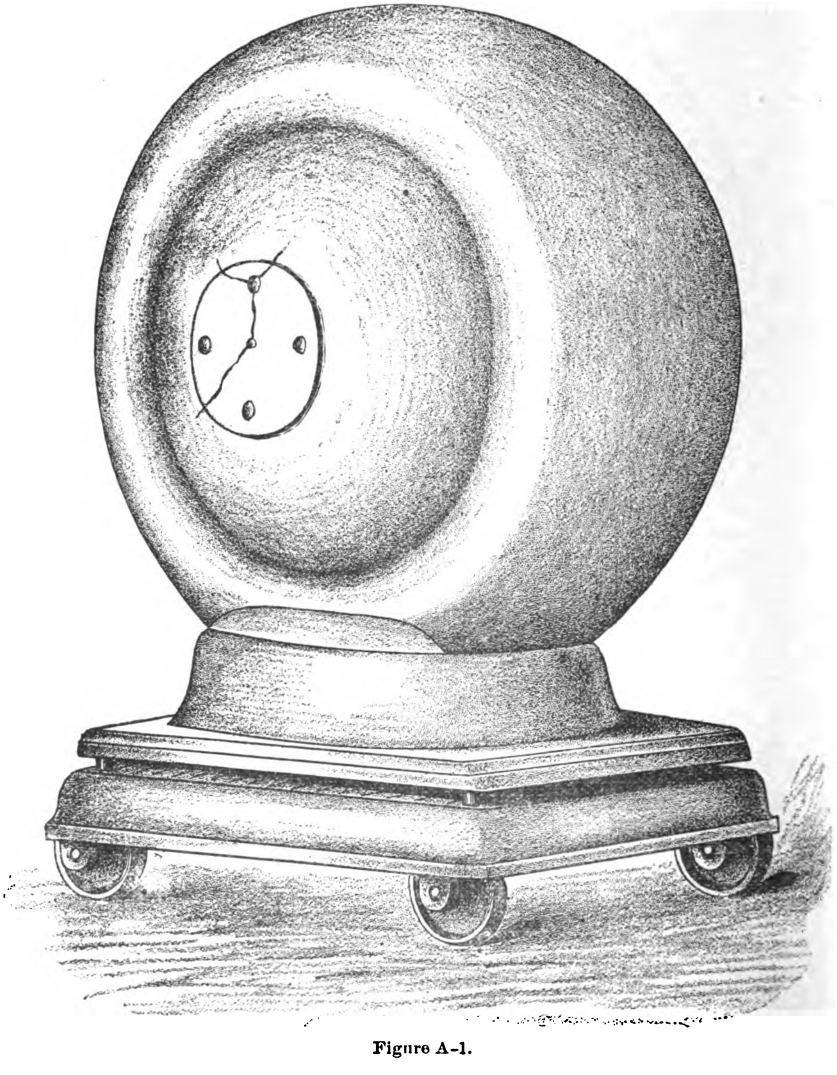


Figure A-1.

Each charge was placed with the ends of the sticks forming it against the half-inch wrought-iron plate over the center of the door, and the detonator in each case was imbedded in the outer end of the center stick of each charge. No tamping was used for any of these charges, and they were held suspended close against the half-inch wrought-iron plate by wires.

The results obtained with each cartridge are given below.

No. 1.—Eight ounces of forcite powder No. 1, a single stick. Result: The half-inch wrought-iron plate was deeply indented and somewhat loosened from its fastenings. No effect was produced either upon the door or the expansion ring.

No. 2.—Sixteen ounces of forcite powder No. 1, two sticks. Result: Two deep indentations in the half-inch wrought-iron plate, but no effect whatever produced either upon the door or the expanding ring.

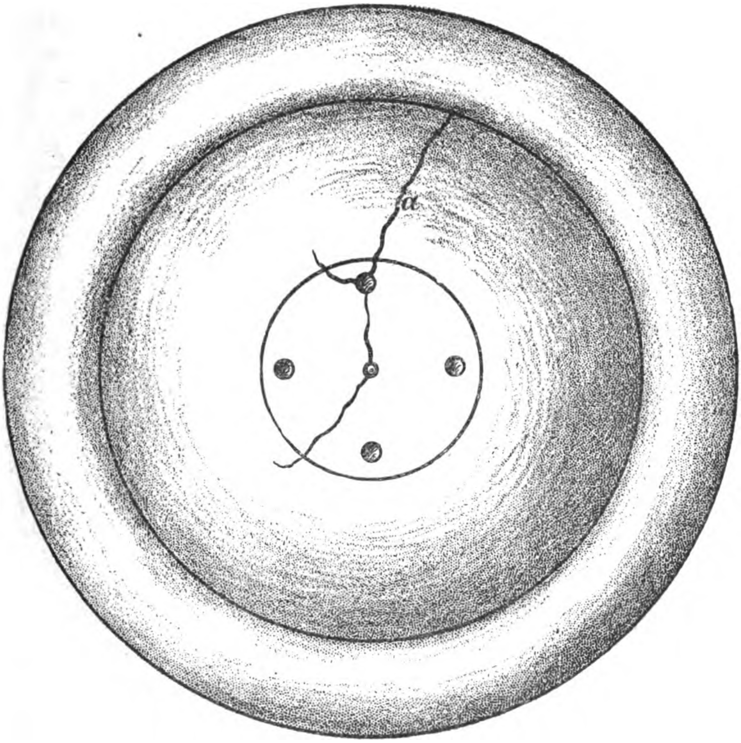


Figure A-2.

No. 3.—Twenty-four ounces of forcite powder No. 1, three sticks. Result: The half-inch wrought-iron plate was perforated and the metal of the door around the center spindle hole slightly fused, but no effect whatever was produced upon the expanding ring.

No. 4.—Thirty-two ounces of forcite powder No. 1, four sticks. Result: The hole in the half-inch wrought-iron plate was considerably enlarged and the metal of the door still further fused and crowded in around the center spindle hole, but no effect whatever was produced upon the expanding ring.

No. 5.—Forty ounces of forcite powder No. 1, five sticks. Result: The half-inch wrought-iron plate was knocked off by this explosion and the crack *a* was extended to the edge of the door, as shown in Fig. A-2. This crack measured about one-sixty-fourth inch in width. The metal of the door was still further fused and crowded in around the center spindle hole, but no effect whatever was produced upon the expanding ring.

No. 6.—Forty-eight ounces of forcite powder No. 1, six sticks. In this and in all succeeding experiments the wrought-iron plate was so placed over the center of the door as to allow us to place our charge upon an uninjured portion of the plate. Result: The explosion of this charge perforated the half-inch wrought iron-plate, and the crack *a* was slightly widened. A piece of metal *b* was spalled off from the edge of the lower spindle hole, as shown in Fig. A-3. The metal of the door around the center spindle hole was a trifle more fused and crowded in, and two more fine cracks, *c* and *d*, were developed in the door. No effect whatever was produced upon the expanding ring.

No. 7.—Fifty-six ounces of forcite powder No. 1, seven sticks. Result: The half-inch wrought-iron plate was perforated and the crack developed by the preceding charges somewhat lengthened, widened, and deepened.

A piece of metal at *e*, preceding figure, was spalled off the edge of the upper spindle hole. The metal of the door around the center spindle hole was a trifle more fused and crowded in. No new cracks were developed, and no effect whatever was produced upon the expanding ring.

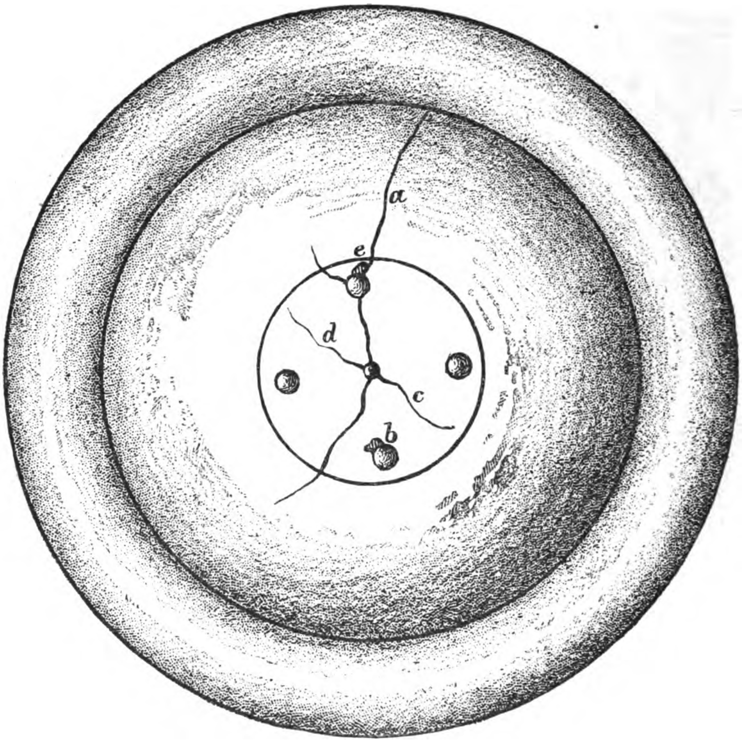


Figure A-3.

No. 8.—Sixty-four ounces of forcite powder No. 1, eight sticks. Result: The half-inch wrought-iron plate was perforated and the cracks previously developed in the door were still further enlarged and extended. The crack *a* being now about three sixty-fourth inches wide. The metal of the door around the center spindle hole was a trifle more fused and crowded in, but no effect whatever was produced upon the expanding ring.

No. 9.—Seventy-two ounces of forcite powder No. 1, nine sticks. Result: The half-inch wrought-iron plate was perforated and several new cracks developed, as shown in Fig. A-4. The metal of the door around the center spindle hole was a trifle more fused and crowded in. By this explosion an effect was produced on the inside of the door for the first time, viz, one upper and one lower lock-plate screw were knocked off. No effect whatever was produced upon the expanding ring.

No. 10.—Eighty ounces of forcite powder No. 1, ten sticks. Result: The half-inch wrought-iron plate was perforated. The cracks shown in the preceding figures were somewhat enlarged. The metal of the door around the center spindle hole was a trifle more fused and crowded in. A small piece of the expanding ring mechanism on the back of the door was knocked off, but no effect whatever was produced upon the expanding ring.

It will be observed that in all of these experiments no effect whatever has been produced upon the expanding ring, nor has there been any tendency toward opening the joint between the door and door jam.

Reviewing these experiments, it is evident that the effects produced by these explosions was localized around the point of application of the different charges; that no increase of charge would produce any effect upon the expanding ring; that the door at the close of the experiments fitted tighter than at the beginning, owing to the development and subsequent enlargement of the crack *a*, and that the cracks developed in the central portion of the door would not have been nearly so marked had the spindles been in place to make up a virtually solid mass of metal behind the explosive.

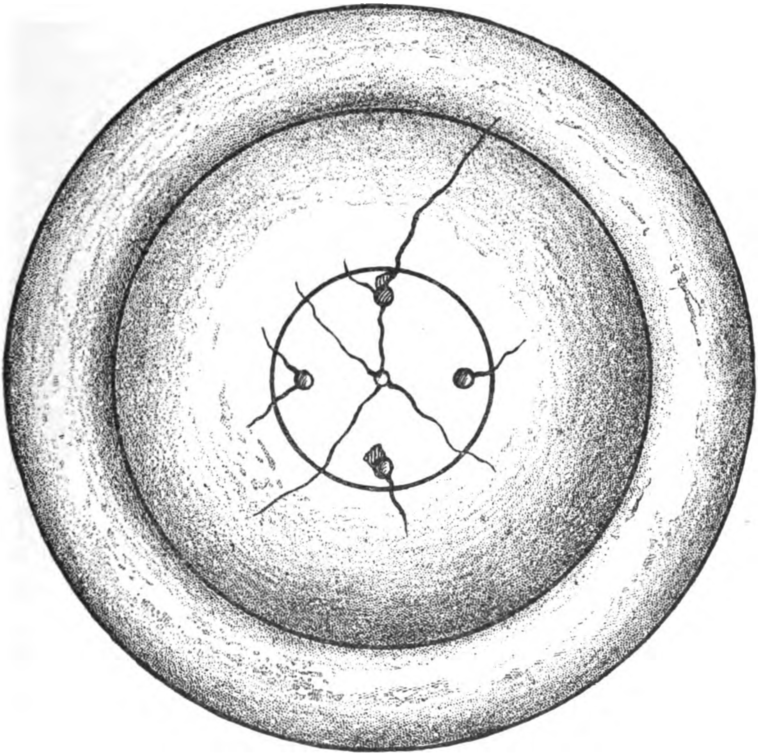


Figure A—4.

In fact, it is exceedingly doubtful if any crack at all would have been developed, had these experiments been made on a sound door with spindles in place. The only object in making these tests, as before stated, was to determine the action of the expanding ring under these several charges of high explosives, detonated upon the face of the door.

There was no perceptible motion in the whole body of the safe to the rear, caused by any of these explosions.

These tests were very severe and far in excess of a practical application of mob violence. Even supposing a mob could attack a Corliss safe door in this manner, the result justifies the conclusion that nothing whatever could be gained towards effecting an entrance into the safe. Everything would, on the contrary, be lost to them when any single portion of the locking mechanism should be displaced by the concussion transmitted from the explosion on the outside, as happened in the case of the tenth explosion, cited above, when a small piece of the expanding ring mechanism on the back of the door was knocked off.

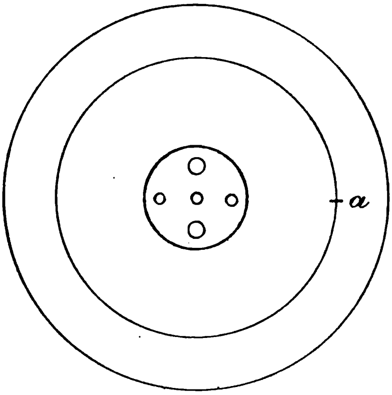
Hence the conclusion must be reached that the Corliss safe door is proof against any mob violence brought to bear against it through the agency of dynamite or other explosives.

SAMUEL RODMAN, JR.,
First Lieutenant, Second U. S. Artillery.

EXPERIMENT JANUARY 28, 1892.

In the following experiments another method of attack upon the door of the Corliss safe was resorted to, viz, exploding a charge of dynamite upon the joint between the door and door jamb to determine what effect, if any, would be produced upon the joint, or rather the edges of the opening at the joint, or upon the expanding ring.

The same 36-inch Corliss safe used in the experiments of January 27, 1892, just cited, was subjected to tests as follows: First, 8 ounces of forcite powder No. 1, a single stick, was laid flat against the joint between the door and door jamb at the point *a*.



A detonator was placed in the middle of the stick and the charge fired.

A careful examination failed to show the slightest effect produced either upon the door, the jamb, or the joint between them. The door was not set back, nor was there any effect whatever produced upon the expanding ring.

Second, 16 ounces of forcite powder No. 1, two sticks, were placed flat against the joint between the door and door jamb at the same point *a*. The two sticks were tied together and the detonator placed in the middle of the outside stick.

A careful examination failed to show the slightest effect produced either upon the door, the jamb, or the joint between them. The door was not set back, nor was there any effect whatever produced upon the expanding ring.

By this experiment it is very conclusively demonstrated that the strength of the construction and of the materials used in the Corliss safe is so great that an attack upon the joint between the door and door jamb with high explosives fails to produce any advance towards demolishing the structure or gaining an entrance to the safe's interior.

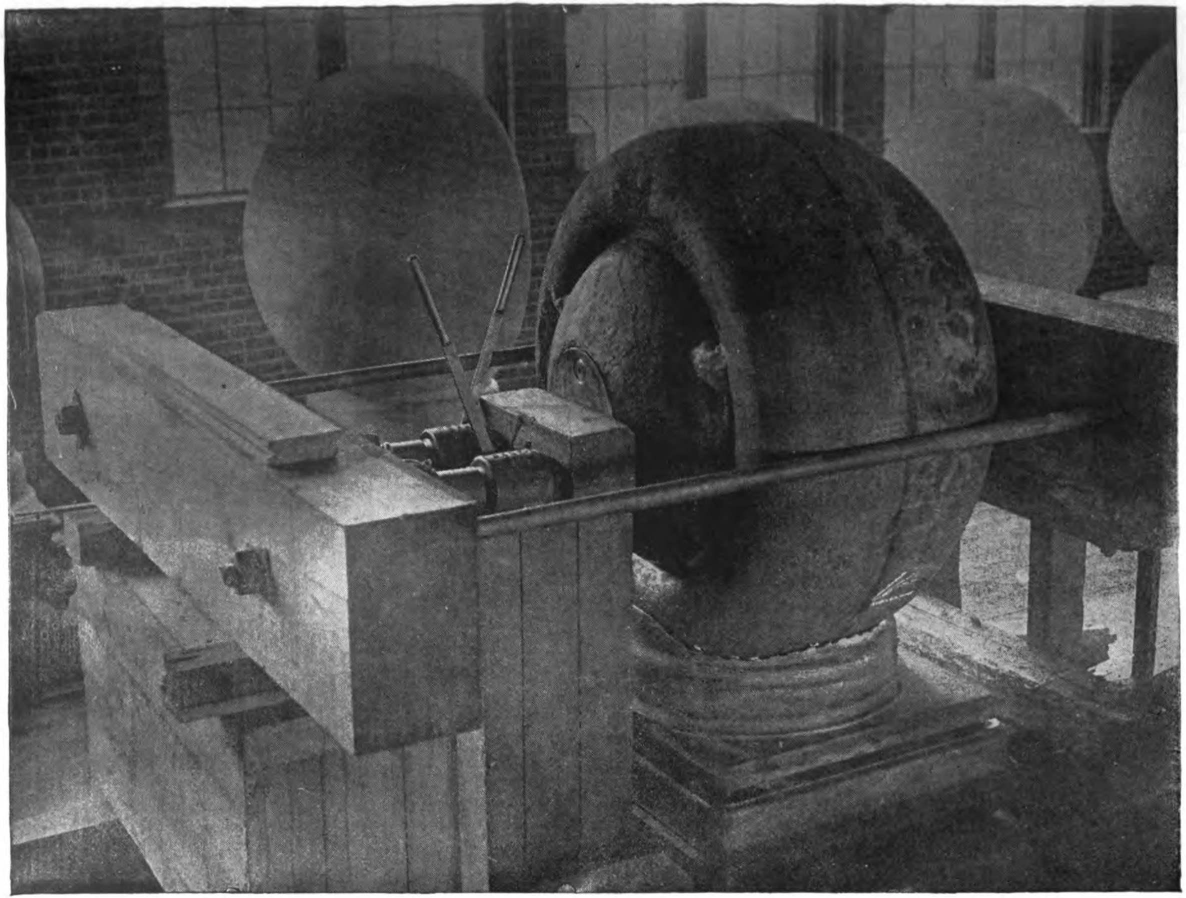
SAMUEL RODMAN, JR.,
First Lieutenant, Second U. S. Artillery.

EXPERIMENT, FEBRUARY 2, 1892.

The object of this experiment was to ascertain what effect, if any, would be produced by a very heavy pressure applied slowly and continuously upon the Corliss safe door, and to note particularly if the expanding ring would be affected or the door forced inward a sufficient distance to allow the introduction of a liquid or liquid explosive between it and the jamb.

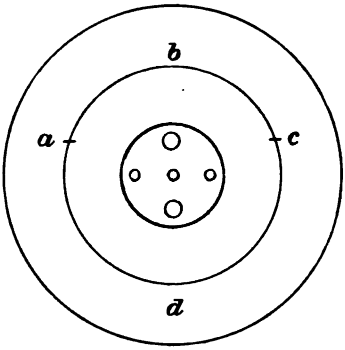
For this purpose the 36-inch safe with ground fitted door, used in experiment of January 16, 1892, was surrounded by heavy rigging shown in the accompanying photograph. The yellow pine beams at front and back are 15½ inches by 9½ inches by 7 feet 3 inches long, and the iron rods making up the other two sides of this frame are 1¾ inches in diameter and 5 feet 6 inches long. They ran through holes 55 inches apart in each of the wooden beams, and were provided with heavy nuts and washers at each end.

This frame or rigging, it is evident from the photograph, formed a backing for the two 15-ton hydraulic jacks, which are also shown in position. The bases of the jacks rested against the heavy beam in front of the safe, and their heads against a



Hydraulic Pressure Applied to the Door of the Corliss Safe to Test the Expanding Ring and its Ability to Maintain the Tightness of the Door Joint.

wooden block 7 inches by 8 inches by 20 inches, placed over the center of the door. The joint between the door and door jamb was puttied on the outside from *a* to *d* to *c*. At *a* and *c* wells of putty were made and filled with water.



It is hardly necessary to add that the door had previously been screwed to its closed position and the ring expanded. Pressure was now applied upon the safe door with the two jacks. They were pumped up as hard as possible in order to develop the full pressure of 30 tons, and this was maintained for 15 minutes. At short intervals the water in the two wells of putty was examined, in order to determine if there was any difference in level owing to any of the water having run in through the joint between the door and jamb.

The unputtied portion of the joint from *a* to *b* to *c* was also carefully watched in order to detect any opening of the joint that might result from the pressure on the door.

The great pressure developed by the jacks caused the beams to bend about ⅜ of an inch at the center, which was only 27½ inches from each of the 1¾-inch iron rods, but the water in the wells of putty remained at a constant height through the entire operation, and the joint from *a* to *b* to *c* was not opened a particle.

Upon removing the jacks and opening the door of the safe the surfaces were carefully examined and no evidence was found that the smallest amount of water had entered the joint. Hence the conclusion from this experiment must be that the Corliss safe door can not be forced in by a very heavy pressure applied slowly and continuously against it, and that the expanding ring is so strong and so well fitted that it will resist an enormous pressure on the outside, far in excess of that to be applied in any practical manner burglariously.

SAMUEL RODMAN, JR.,
First Lieutenant Second Artillery, U. S. Army.

CORLISS SAFE AND VAULT DOOR CO.,
Providence, R. I., March 4, 1892.

MY DEAR SIR: In response to what I understand to be your wish, as expressed or intimated in your very polite letters of January 25 and February 1, I beg to submit for the consideration of your Commission my views on the subject of safe and vault construction for the settlement of which question your Commission was created by Congress at the suggestion of the late Secretary of the Treasury, Mr. Windom.

You will, I am sure, pardon me if I write very earnestly and frankly on the subject and if I seem to indicate to the Commission my views regarding what I think should be their conclusions in view of all the facts that have been brought before them.

It is now some years since my attention was accidentally called to the subject of safes and vaults. Being entirely ignorant regarding the state of the art and the system of construction in vogue, I naturally supposed that there were a multitude of burglar-proofs in the market, and that therefore the only questions to be considered in making a purchase were such minor considerations as convenience of use, nicety of construction, and price.

Notwithstanding the fact that safemakers had vied with each other for years in their efforts to exhaust the adjectives in our language in support of their claims, a superficial examination of the subject awakened misgivings regarding the fundamental question at issue, viz, the burglar-proof qualities of the safes that were offered. These misgivings led to a more thorough investigation of the subject, and resulted in the discovery of the fact that there was no really burglar-proof safe made. Further investigation, and due consideration of the subject, established in my mind a conviction that it was utterly impossible to produce a really burglar-proof structure by the piecemeal method of construction necessarily adopted in building rectangular safes and vaults.

In the consideration of this subject, the fact should be borne in mind that the great mass of people, although they are deeply interested in the result, and would be intensely interested could they know the facts as they are developed, practically know nothing of the merits of the question. Even bank officials and others, who are the custodians of the portable wealth of the world, are without any, or at least any considerable, knowledge of the matter. Their experience in purchasing and using safes and vaults, even though covering a lifetime, constitutes no qualification whatever for expert opinion upon the mechanical or scientific questions involved, nor does their education and experience qualify them to combat fallacious arguments or detect sophistry in the discussion of this question by those whose business interests would seem to imply a thorough knowledge of the subject in all its bearings.

Having been, as it were, drawn into the investigation of this subject while acting as a bank director in pursuit of a burglar-proof, and discovering that no burglar-proof structure could be procured, I became strongly impressed with the vital importance of the subject and thoroughly imbued with the absolute necessity that some construction should be devised by which the funds of our moneyed institutions might be made more secure, and the rapidly accumulating wealth of the world could be preserved from the depredations of lawless men. To the accomplishment of this end, I abandoned a prominent position in the steam-engine business, as you know, and have devoted several years of my life and a large amount of money. As a result of my labors (and to this date I might add my sacrifices) the world is in possession of a system of safe and vault construction that is absolutely burglar-proof, and that affords, in my opinion, all the practical security demanded against mob violence.

At the time I had the honor of presenting this subject to Secretary Windom there was pending in Congress a bill appropriating about $330,000 for improved vault facilities for the Treasury Department, the immediate passage of which was strongly urged by the Secretary. Upon hearing my statements and explanations, and examining my models and the documentary evidence I offered, he said that he did not feel himself competent to decide a question of this kind where so much was involved and added, "It is too deep for me. If this bill passes I shall appoint a competent commission to thoroughly investigate this whole matter and settle it for me." The bill making the appropriation for the vaults was not passed, but the clause authorizing the appointing of the Commission was passed and is the authority under which the Commission now exists.

If I remember correctly, you stated when here that the Commission had not been invited by anybody but ourselves to witness tests or demonstrations of any kind. Is not this fact very significant? Is it not fair to assume that the proprietors of the different establishments that you officially visited would gladly have embraced the opportunity to afford the Commission some substantial, some practical evidence of the security afforded by their construction, if indeed it were possible to offer any tangible evidence?

In the absence of any such action on their part, is it unfair or unreasonable to infer that their unanimous course in this particular was prompted by a knowledge of their own faulty construction, coupled with a respectful appreciation of the practical ability of the Commissioners?

Secretary Windom, I am quite sure, comprehended the difficulty that confronted him in the consideration of this question. He appreciated the fact that large sums of money were being spent annually for vaults and safes. He realized that if any one system of construction extant was preëminently better than all others, the fact should be established and that system should be made the standard. To ascertain the truth as to this question, and to "settle the matter," he determined to appoint a commission. No such commission was ever before created. The Government and the banker has heretofore blindly followed the recommendation of safe makers, and it is now proposed to determine the question by a competent commission of disinterested experts, to whose conclusions no one but the safe maker whose constructions are condemned as insecure will ever offer objection.

If the Commission shall find a system of construction that really affords security, the Government and the community at large are entitled to know that fact and to know what it is, that no more money may be expended by those who are not competent to investigate the subject for themselves upon insecure constructions, and also to the end that the public may not repose confidence in structures that afford no adequate security.

It is impossible to measure the importance of the Commission's work. I doubt if the Commissioners themselves, at the commencement of the investigation, fully appreciated the results that might arise from their labors.

It has been stated that ninety-nine one-hundredths of the portable wealth of the world is stored in safes and vaults. If, in the pursuit of their investigations, the Commission have discovered that those safes and vaults are, in reality, very insecure, and that the confidence reposed in them is based upon ignorance of mechanical and scientific principles, rather than upon sound reasoning and fact, certainly the Commission will have done the community some valuable service. If they discover a remedy for this defect, and announce that fact through the Secretary of the Treasury, they will have done a far greater service.

I am not blind to the fact that safe makers will be terribly chagrined and displeased if you report the whole truth regarding the weakness of their construction. Most assuredly they will seek by every means in their power to neutralize your statements and to discredit your opinions; but if they dare to question the soundness of your conclusions, invite them to send specimens of their constructions to the Commission, promise them a fair and impartial test, at the same time assuring them that if you have erred in judgment the error will be cheerfully corrected. If, on the other hand, your judgment is confirmed, the safe makers must abide the result, and the whole community will echo, Amen.

As stated to you in a previous communication, I feel that it is a difficult and delicate matter to determine just how much of the truth established by our demonstrations, made in your presence, should be revealed and how far it should be made public.

By reference to the act of Congress under which the Commission was appointed we find it to be as follows:

"To enable the Secretary of the Treasury to appoint a commission of scientific or mechanical experts to report on the best method of safe and vault construction, with a view of renewing or improving the vault facilities of the Treasury Department."

A strict interpretation of the duty of the Commission is, therefore, to ascertain and report what is the "best method" of safe and vault construction.

So far as we are informed only three systems or methods of construction are under consideration.

First, the laminated system.

Second, the Hough and Harper construction.

Third, the Corliss system of construction.

The laminated construction has been for all time the prevailing custom. When mankind first sought a locked receptacle for valuables a wooden box or chest was made. Later on the wooden box was lined with iron; then came the iron box; still later came the steel lining, and finally the welded steel and iron box. These several steps in the process of evolution were the product of the ironmaster, not the safe-maker. The safe-maker has never been known to get beyond the idea of a square box. Competition in manufacture has always been confined to barter and to details in the manner of putting together plate after plate, rather than to any radical improvement. Hence, we find all othodox safe-makers a unit in their antagonism to any new process of safe construction.

The inherent defects of the laminated system of construction being so plainly evident it is surprising that at this stage of the world, at this period of progress in the arts and sciences, its use has not become entirely obsolete.

The practical demonstrations made by us in the presence of the Commission have established the fact beyond all possibility of doubt or denial that it is practically impossible by the laminated system of construction to make a burglar-proof structure.

Of course, your report to the Secretary of the Treasury will state this fact.

As to the vault construction suggested by Messrs. Hough and Harper. In the absence of any practical tests we assume that the Commission will be obliged to form their conclusions as to its merits upon a mental analysis of its construction in the light of their own experience, aided, perhaps, by the ocular demonstrations they witnessed when here.

I am personally cognizant of the fact that the idea of this Commission was conceived and the appointments were made for the specific purpose of obtaining a formal expression of opinion as to the relative merits of the Corliss system of safe and vault construction and the laminated system of construction, or any other method of construction that may be brought to their attention by gentlemen thoroughly qualified by education and experience as engineers and mechanics to make the necessary investigations and to determine the question.

The Commissioners will certainly accord to us the credit of having afforded them every facility in our power to thoroughly investigate theoretically and practically the subject under consideration, both with reference to our own construction and all others.

The tests and demonstrations made were of incalculable value, for they established many facts that could not with certainty be determined otherwise.

Our only regret is the fact that the gentlemen of the Commission were unable to give as much time to the subject, especially as to the practical demonstrations, as we had hoped, for we were ready and anxious to go to the bottom of every question and settle every point raised by actual demonstration, to the end that the main question might be determined beyond the possibility of controversy.

In our opinion enough has already been done to establish the facts necessary to a determination of the relative value of the different methods of construction, and as this is the main question at issue further investigation may not be absolutely necessary to a fulfillment of the duties of the Commission, but further investigation would be valuable and may be necessary, for if any interested parties take exception to the terms of your report they should be answered by the Commission.

We hope that Secretary Foster will see the reasonableness of this and decline to dismiss the Commission upon the rendering of their report. They should be retained so as to be able, if necessary, to defend the position they shall have taken regarding the question submitted to them. If interested parties claim to have been wrongly adjudged, let them be invited to send to the Commission specimens of their manufacture to be tested. Any manufacturer who confidently believes his construction to be burglar proof will certainly not demur at this.

By this means the "chaff" will eventually be sifted from the "wheat" and the question will be effectually settled.

In the study and investigation of this subject we have devoted years of time and a very large amount of money. We unhesitatingly venture the assertion that the aggregate of time and money expended by us in this direction and in our efforts to produce a remedy for the dangers that threaten the treasure of the world, is greatly in excess of that expended by all others who have labored in this direction combined together. Therefore, we have felt that we are entitled to that consideration we ask, viz: a thorough and comprehensive examination, that the merits of the case may be authoritatively and wisely determined and made known. More than this we do not ask. Less than this would be an injustice to any one who has labored for the accomplishment of a meritorious end, the successful achievement of which is of great public interest and for the general good of mankind.

In the decision of the question involved somebody must be aggrieved; it is impossible to avoid it. A truthful statement of the salient points will most certainly displease one class; a withholding of such statement will displease others and disappoint all.

When the banking fraternity become fully advised of the object and scope of the Commission's work they will look to your conclusions and follow them implicitly, unless, indeed, your conclusions are successfully controverted. To avoid any such contingency we have sought by every means in our power to show and convince the gentlemen of the Commission what the facts are and upon what ground they can stand unmoved by any assault.

Pardon me for inflicting upon you such a lengthy communication. If any apology is needed it may be found in the fact that you have asked me to state, for the benefit of the Commission, all points that I deem necessary to a full understanding of the matter under consideration.

Very respectfully yours,

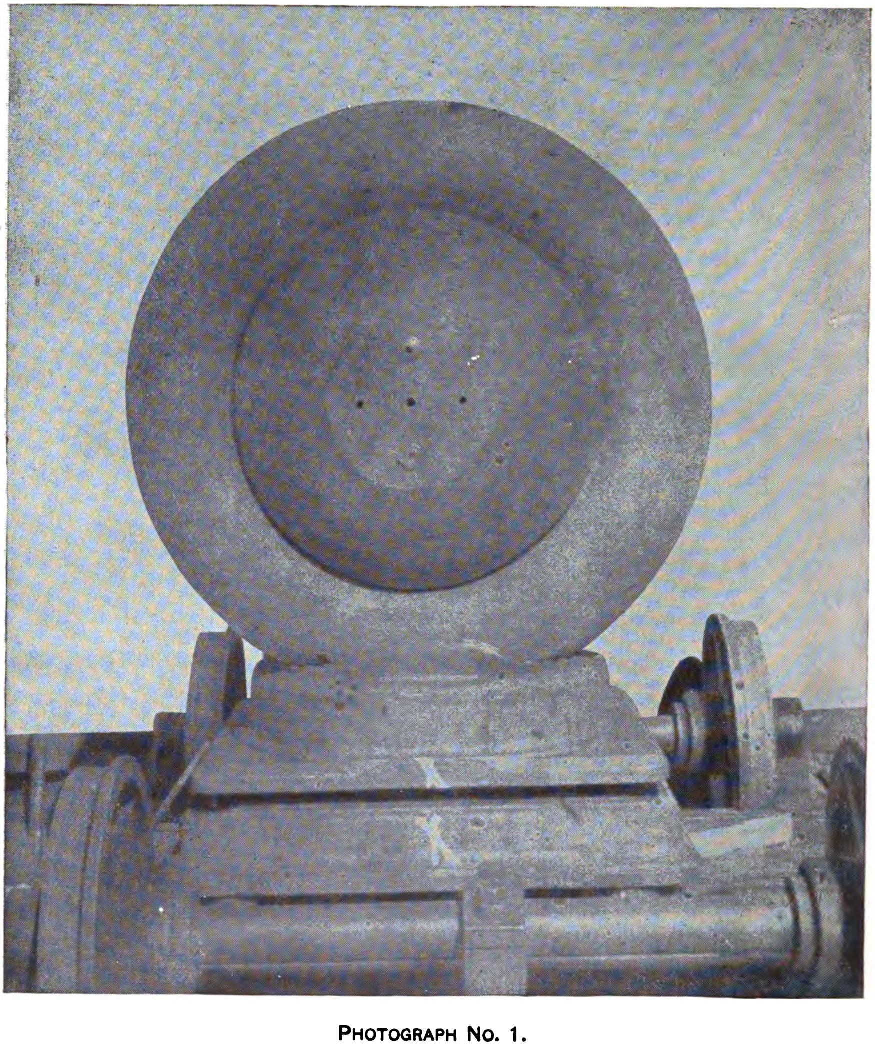
WILLIAM CORLISS.

Dr. ROBERT H. THURSTON,
Chairman Treasury Commission on Safe and Vault Construction, Ithaca, N. Y.

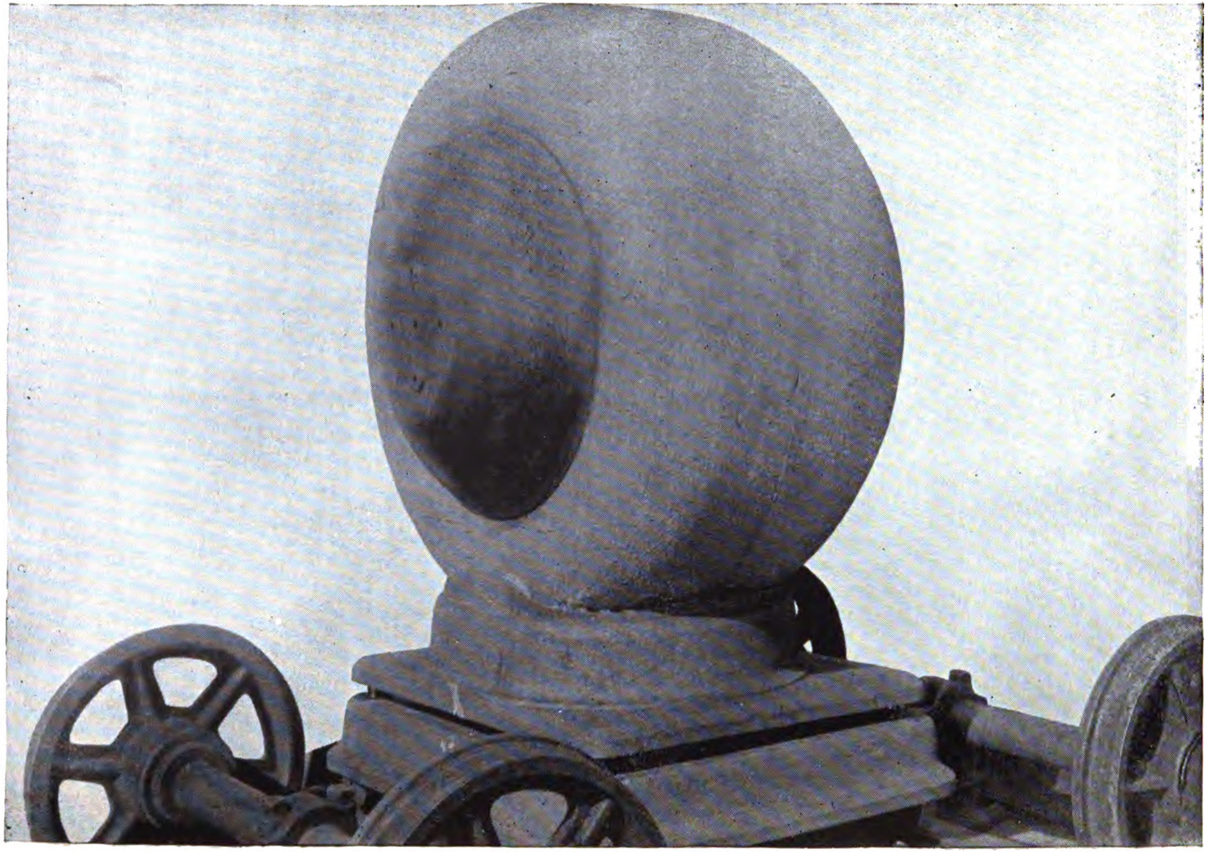
RECORD OF DEMONSTRATIONS MADE IN THE PRESENCE OF FRANCIS A. PRATT, ESQ., MEMBER OF THE TREASURY COMMISSION ON SAFE AND VAULT CONSTRUCTION, AT THE WORKS OF THE CORLISS SAFE AND VAULT DOOR COMPANY, ON MARCH 5, 1892.

It will be remembered that upon the occasion of the visit of two members of the Treasury Commission, viz: Dr. R. H. Thurston and Theodore N. Ely, Esq., on December 29 and 30, 1891, after they had witnessed a number of demonstrations, both upon the Corliss safe and upon a safe built upon the laminated system of construction, and after these gentlemen had left the works and were on their way to Providence, Mr. Ely suggested that certain experiments should be made upon the Corliss safe. These experiments were most carefully and thoroughly executed, carrying the tests considerably beyond the limits of ordinary practicability, and an account of the same, with the effect produced and conclusions reached, are embraced in the report of operations conducted before the Treasury Commission and of experiments conducted at their suggestion.

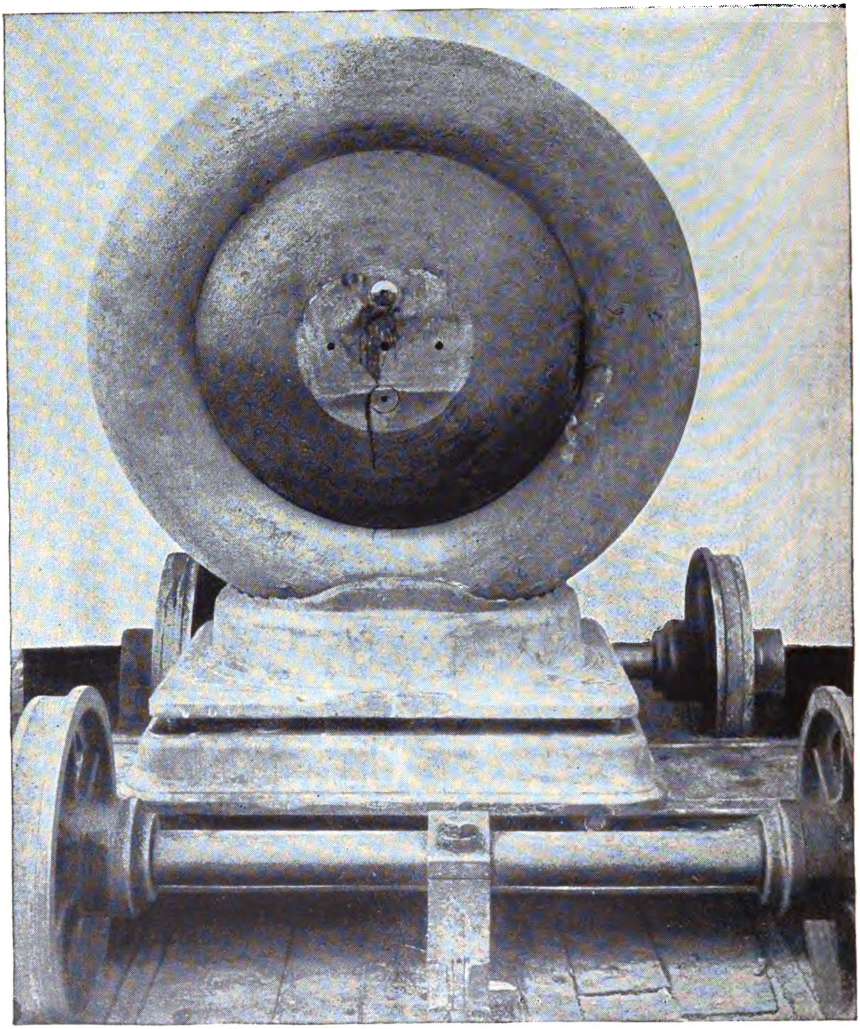
Upon the occasion of Mr. Pratt's visit, time was wanting to repeat these experiments in detail; all but one, however, were repeated, and in those instances where



PHOTOGRAPH NO. 1.



PHOTOGRAPH No. 2.



Photograph No. 3.

high explosives were used the final and heaviest charge that had been noted was applied. The experiment omitted was the one where it was sought to determine the effect produced by a charge of nitroglycerin introduced between the door and jamb of a safe whose door and jamb were simply machine turned. This demonstration, however, was not necessary, since all the doors of the Corliss safe are now ground to a perfect fit, and since it is necessary to produce some opening before a liquid explosive can be introduced, which it will be noted by a perusal of the following report was not made.

The experiment of exploding a charge of forcite powder No. 1, noted below, upon the joint between the back and front of a Corliss safe was suggested by Dr. R. H. Thurston, and has not previously been reported to nor witnessed by the Commission.

EXPERIMENT No. 1.

In the demonstrations made upon the Corliss safe, a 36-inch safe complete and set up as for use was taken. It had a ground-fitted door. The upper and lower spindles were in position, the other three were left out. The safe standing on a truck just as it was used in the demonstrations is shown in photographs Nos. 1 and 2.

The door was screwed to its closed position and the ring expanded. A half-inch wrought-iron plate about 6x10 inches was laid flat against the face of the door and firmly lashed into close contact with it. A 5 pound cartridge of forcite powder No. 1, made up into a cylindrical bundle of ten sticks, was placed with one end resting against the wrought-iron plate and directly over the center of the door. It was firmly held close against the plate by wires and a detonator imbedded in the outer end of the center stick of the bundle. This charge was detonated, and the wrought-iron plate, which bounded off about 20 feet to the front, was nearly punctured. There was not the slightest effect to be noticed upon the surface of the door save a blackened appearance and a small indentation in the head of the upper spindle caused by the wrought-iron plate. Photograph No. 3 shows the front of the safe after the explosion.

To determine whether the door had been set back any by the tremendous blow given to it by this charge, a well of putty was made at the point *a* (see Fig. *b*-1) designated by Mr. Pratt, and water poured into it. Owing to the fact that the putty did not adhere well to the iron of the safe some of the water leaked out. The leak was stopped and the water allowed to stand in the well for five minutes.

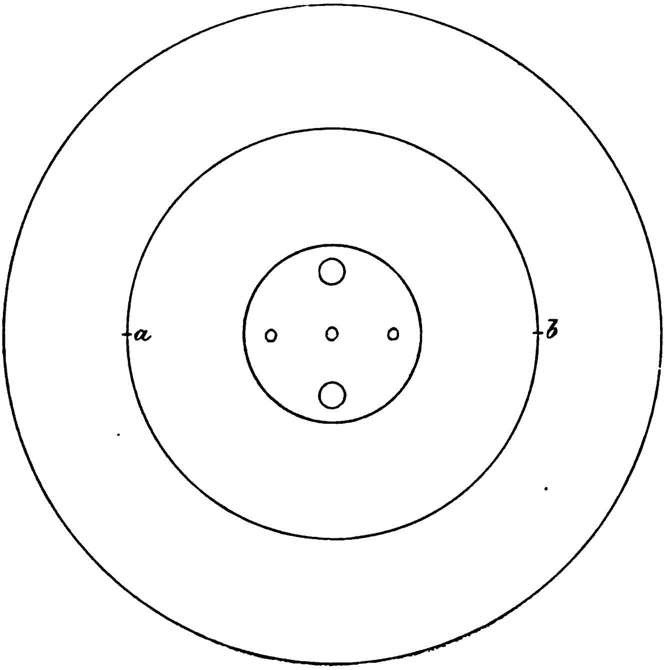


Figure *b*-1.

An attempt was then made to open the door in order to examine the steps of the door and jamb at *a* and determine whether any water had run in, but the upper spindle refused to work. Several unsuccessful attempts were made to operate the upper spindle on the afternoon of March 5 and during the morning of March 7, (March 6 being Sunday) and on the afternoon of March 7 the back was unscrewed from the front, disclosing the interior.

It was noted that no effect had been produced by the explosion upon any part of the locking mechanism, but the spindle had been so upset that it could not be turned.

On the afternoon of March 8 the upper spindle was bored out in a boring mill, the door set back, swung around, and it was then determined that no water had entered the joint between door and jamb. The expanding ring had not been effected in any way. The truck upon which the safe stood ran back 1½ inches from the effect of the explosion.

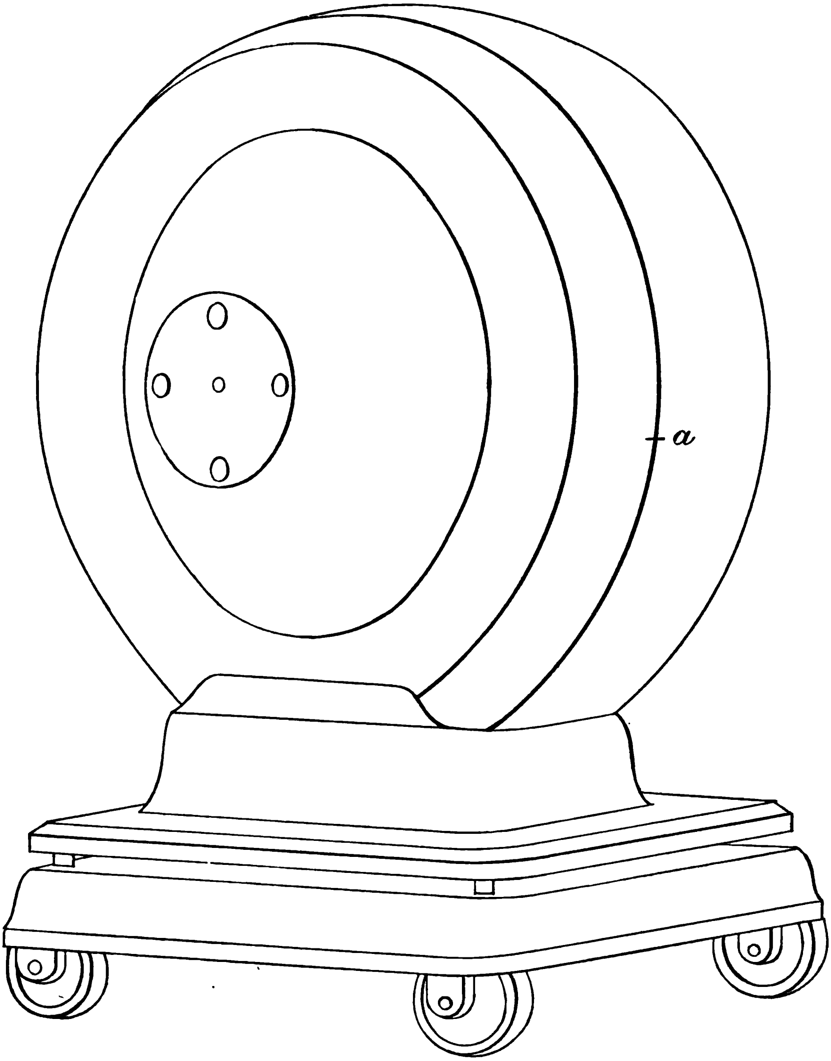
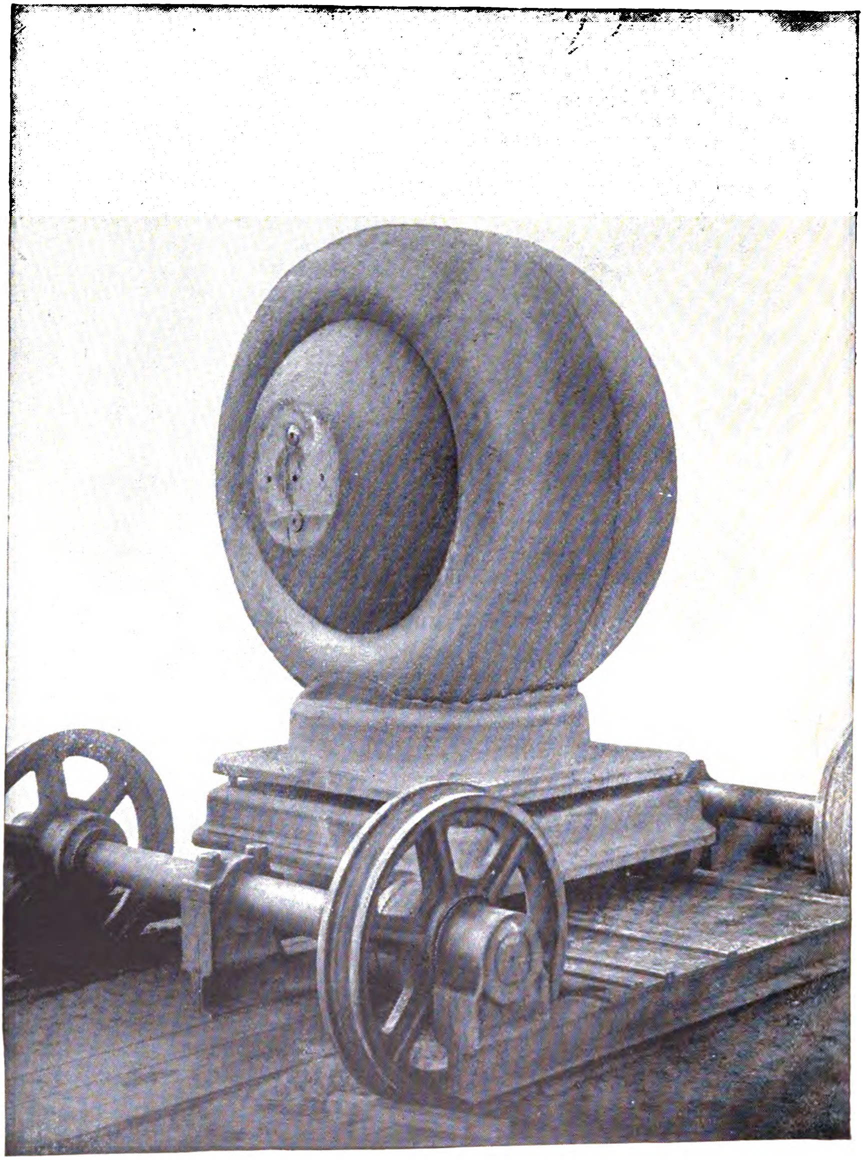


Figure *b* 2.

Hence the conclusion must be reached that the Corliss safe door and expanding ring are proof against any attacks directed towards driving the one in and upsetting the other by the detonation of a large mass of explosive on the outside.



Photograph No. 4.

EXPERIMENT No. 2.

The same safe was used in this demonstration, and the object aimed at was to determine what effect, if any, would be produced by the explosion of a charge of dynamite placed on the joint between the back and front of a Corliss safe.

For this purpose a cylindrical cartridge of forcite powder, No. 1, made up of five sticks and weighing 2¼ pounds, was placed with one end firmly against the joint between the back and front, at the point *a*, shown in the following Fig. *b*-2, and held securely in position by wires. The detonator was imbedded in the outer end of the center stick of the cartridge.

The result of the explosion was absolutely nil as regards opening in the slightest degree the joint between the back and front, and a reference to the photograph No. 4 will show that the only effect produced was a cleaning off of the surface of the iron immediately under and around the point of application of the charge.

This experiment very conclusively demonstrates that the Corliss safe is proof against any attack directed towards opening the joint between the back and front by the detonation of a mass of dynamite or other high explosive placed against this joint.

EXPERIMENT No. 3.

The demonstration made in this case was the placing of a charge of forcite powder, No. 1, directly against the joint between the door and jamb, and, exploding the same, to determine what effect, if any, would be produced upon the expanding ring or towards opening the joint sufficiently for the introduction of a liquid explosive.

The same 36-inch Corliss safe was used. A cartridge of forcite powder, No. 1, weight 1 pound, made up of two sticks, bound together by wire, was laid flat against the joint between the door and jamb at *b*, shown in the Fig. *b*-1. The detonator was imbedded in the center of the outer stick of the charge.

After the explosion a well of putty was made at *b*. Water was poured into this well and allowed to stand for five minutes. At the end of this time its height in the well remained unaltered.

When the door was opened, three days afterwards, on March 8, there was no indication of any water having run into the joint at the point *b*. There was a blackened appearance to the outer step of door and jamb, showing that the gases of explosion had penetrated somewhat even this almost absolute fit, but they had not separated the joint between the door and jamb so as to allow the introduction of any liquid explosive. The expanding ring was not affected.

A careful inspection and comparison of photographs Nos. 2 and 4, No. 2 taken before and No. 4 after the explosion, will show that no effect whatever, beyond a cleaning off of the surface of the iron around the point of application of the charge, is noticeable.

The conclusion to be reached from this demonstration is that the Corliss safe is proof against that attack which would be directed towards opening the door by the detonation of a mass of explosive placed upon the joint between the door and jamb. Any charge of practicable size will produce no effect whatever, either upon the door, the jamb or the expanding ring, so that it would not be possible, subsequent to such an explosion, to introduce any liquid explosive into the safe.

EXPERIMENT No. 4.

A Herring vault door, which is shown in photographs Nos. 30, 31, 32, and 33 in the Report on Preliminary Experiments and Mechanical Burglaries, was now operated upon.

This vault door was built for the Mercantile National Bank of New York City, and, as shown in the photographs referred to, had previously been operated upon in the presence of prominent bank officials by the cutting of two 4-inch holes through it.

The plates of this door are as follows: First plate, welded iron and steel (presumably chrome) one-half inch thick; second plate wrought iron, one-half inch thick; third plate franklinite, 1-inch thick; fourth plate wrought iron, one-half inch thick; total thickness of door, 2½ inches.

Behind the fourth plate and bolted to it was the massive bolt-work common to laminated constructions.

Three men, at 11.19 a. m., began to get together the necessary burglar's tools.

At 11.23½ a. m. heat was applied to the outside plate and continued until 11.49½ a. m., twenty-six minutes. The heat was then taken off and while the plate was cooling the burglar's rigging was set up in front of the vault door.

At 12.09 p. m., the outer plate of the door being sufficiently cooled, the 4-inch cutter was applied, and at 12.29 p. m. the first plate of welded iron and steel was cut through and taken out. Time of cutting, twenty minutes.

The 4-inch cutter was applied to the second plate at 12.30 p. m. and at 12.38 p. m. the second plate of wrought iron was cut through and taken out. Time of cutting, eight minutes.

The rigging was then removed and at 12.39 p. m. operations upon the third plate with punches and sledges were commenced, and at 1.01 p. m. a hole 4 inches in the clear was punched through the third plate of franklinite. Time, twenty-two minutes.

The rigging was now set up again and the 4-inch cutter was applied to the fourth plate at 1.04 p. m., and at 1.17 p. m. the fourth and last plate of wrought iron was cut through and taken out. Time of cutting, thirteen minutes.

The time occupied in the entire operation, performed by three men, from 11.19 a. m. to 1.17 p. m. was therefore one hour and fifty-eight minutes, and the result was a 4-inch hole cut clear through the door.

As stated before, two 4-inch holes had previously been cut through this door. The time of each of these holes is as follows: First, two hours and sixteen minutes. This included cutting the 4-inch hole, disconnecting the lock, and opening the door. Second, two hours and one minute. Third, one hour and fifty-eight minutes.

The total time therefore for these three operations was six hours and sixteen minutes, and it represents the time necessary to cut a 4-inch hole clear through a first-class piece of laminated work, 7½ inches in thickness, and disconnect the lock. Burglars certainly have this time at their disposal any night.

Suppose them to have thirty-six hours under the most favorable conditions, then at the rate of cutting done in these three operations cited above, viz, 1.2 inches per hour, they could cut through 43.2 inches of laminated work such as the above.

EXPERIMENT No. 5.

This demonstration was simply a repetition of that mentioned in the report of experiments suggested by Mr. Ely, where two 15-ton hydraulic jacks were used to test the strength of the Corliss safe door and expanding ring to resist a heavy and continued pressure applied to the center of the door. The same safe, riggings, and jacks were used as have been described in that experiment, and every detail carried out in the same way.

Pressure was applied to and kept upon the door for ten minutes, each jack being pumped up to its full capacity and kept there. No water ran into the joint between the door and jamb from the wells of putty, and no effect whatever was produced upon the expanding ring.

The door of the Corliss safe and the expanding ring have now been tested by two extreme pressures:

First, by an enormous pressure instantaneously developed by the explosion of a mass of dynamite on the face of the door.

Second, by a heavy and continued pressure on the face of the door through the agency of hydraulic jacks, and no effect has been produced in either case upon the door or the expanding ring. Any other kind of pressure must be found somewhere between these two extremes, as, for instance, that of a battering-ram, and it is perfectly fair to conclude that it is an impossibility, by any means within the limits of practicability, to force the door of the Corliss safe in or to upset or destroy the expanding ring.

SAMUEL RODMAN, JR.,
First Lieutenant, Second U. S. Artillery.

The foregoing is a correct transcript of demonstrations made before me as United States commissioner on safe and vault construction at the works of the Corliss Safe and Vault Door Company, March 5, 1892.

F. A. PRATT.

STANDARD SPECIFICATION OF WORK AND MATERIALS REQUIRED IN CONSTRUCTION OF VAULT, VAULT DOORS, AND THE GRILLE DOORS, WITH THEIR LOCKS, FOR A SAFE DEPOSIT.

WORKMANSHIP AND MATERIALS.

The entire work to be done in the best and most workmanlike manner; all materials used to be new and of the best quality used for such purposes, and to the satisfaction of the company and to the superintendent of the work.

The welded steel and iron to be five-ply, made up of three plates of wrought iron and two plates of chrome cast steel, rolled together, the finish thickness of same to be half inch and one inch, respectively, and the bolts to be made of the same materials. All of the welded steel and iron to be of the Chrome Steel Company's (of Brooklyn, N. Y.) manufacture (except for the tongued and grooved bars, and their brand to be on each bar, and all steel of the welded steel and iron in bolts and bars to be hardened drill proof). All materials to be of of uniform thickness, of smooth plates, and free from rust or scale; bolts securing plates together to be not less than three-fourths of an inch in diameter, all screwed into holes having perfect threads and to fit well into holes and set up with a set of pall wrench until they are tight and plates are close to each other, the holes to be filled with fire clay before being put into furnace for hardening to prevent damage to threads.

DAMAGES AND DELIVERY.

The contractor to be responsible for any damage to the building or to person or persons in the delivery, erection, and completion of the work, and to obtain all permits that may be required.

The contractor is to furnish all skids, floor planks, and other requirements, so as to deliver the work without damage to the building, and, if necessary, do whatever shoring that may be required in carrying over very heavy pieces of work so as not to damage or set the beams of the building.

The contractor is to deliver the entire work set up in place ready for use with necessary leveling pieces, together with all the work contained in these specifications, on or before March 15, 1892, under a liquidated damage penalty of $50 a day, and to so arrange the delivery of the work that it will not interfere in any way with the other mechanics engaged in the building in their work, and to furnish the plates to go under vestibules when required.

DRAWINGS.

All drawings are the property of the company and are to be returned with the specifications with the bid, and also by the contractor on the completion of the work.

The plans and specifications are to coöperate and is to include all work shown in color, to be made in the best and most workmanlike manner and of the best materials and construction, and is to cover all work in accordance with same and as will be directed by the superintendent of the work; and the contractor is to furnish all work called for in these specifications or shown in plans.

The measurements are taken from the plans in the office of ——— architect, and are believed to be correct, but to be verified by the contractor, and who is to be wholly responsible for fitting his work to existing work, and to conform with work to be fitted into building.

DIMENSIONS.

The safe deposit vault to be 8 feet 6 inches high, 22 feet wide, and 16 feet 6 inches deep on the outside from corner to corner, exclusive of the projection of the vestibules.

The entrance door of the safe deposit vault to permit of a clear opening of 6 feet 8 inches in height, and 2 feet 8 inches in width. The opening in the wall for these doors is to be left by the masons 8 feet 7 inches in height from the beams on which the vault rests to the lintel, and 5 feet 2½ inches in width.

The rear door for the safe deposit vault is to have a clear opening of 2 feet in height and approximately 1 foot 6 inches in width. The opening to be left by the masons to be 4 feet 3½ inches in height and 4 feet 1 inch in width. The vestibules to be made of a sufficient depth so that the front face of each will come flush with the face of the plaster or finish on the wall.

The opening for the grille door is to be left by the masons 8 feet 7 inches in height, and 5 feet 8 inches in width.

The opening for the front door is to be left by the masons 8 feet 1½ inches in height and 5 feet in width.

The opening for the smaller door to the storage vault is to be left 3 feet in height and 4 feet 1 inch in width.

The above dimensions as to opening of the wall, etc., are assumed to be correct, but the contractor is to be responsible for all measurements and is to verify same at the building.

CONSTRUCTION OF SAFE DEPOSIT VAULTS.

The entire work, excepting doors and vestibules, to be put together in place on the foundation, plate after plate, edges of all plates to be planed and ground true and perfect to make perfectly tight joints throughout, the plates to be closely bound together and set up with a set, or set up with a heavy pall wrench. No tap bolt is to go through more than two plates and those on the outside securing the 1-inch welded steel and iron plates, and also the 1-inch steel plates to be blind bolts and are not to go through the plates or show on the outside.

SHELL OF VAULT.

All the outside corners to be made of 6 by 6 by 1 inch angles of welded chrome steel and iron.

The space between these angles to be filled in with plate of 1-inch welded steel and iron; second, one-half inch welded chrome steel and iron; third, one-half inch welded chrome steel and iron; fourth, one-half welded chrome steel and iron; fifth, one-half inch welded chromes teel and iron; sixth, one-half inch steel plates (except at the bottom, where two plates of one-fourth inch steel will take the place of the one-half inch plates, and as hereafter specified), making a total thickness of 3½ inches of actual metal. The angles covering the outside corners of vault to be bent and welded at the corners with an angle at least 12 inches long, to be welded to these angles, forming a solid tripod; the edges of all angles covering all the corners of vault to have their edges rabbeted about one-half their thickness and with one-half inch of lap, the ends of all these angles to be rabbeted in the same manner as those they abut.

All the 1-inch plates also to be rabbeted to each other and with the rabbets in the angles and frames to make a close fit. The 1 inch plates to be not less than 20 inches in width and are in length to reach from angle to angle, except for the top and bottom, these plates not to be in more than two pieces and not to come in line by 1 foot. The balance of the welded steel and iron and steel plates to be so placed as to break joints with each other throughout the entire structure and no bolt to be placed opposite any other.

The inside steel plates to be bent into angles on all the inside corners and not to be less than 8 inches on one angle or less than 12 inches on the other, and the eight inside corners of vault to have the steel plates bent into right angle triangles or tripods.

The floor plates between the corner angles to be made of two plates, the under one to be made of smooth plates and the exposed one to be made of rough rolled steel of a pattern selected by the superintendent of the work, as the plates are not rolled and cut square with the pattern the plates are to be ordered several inches longer than required and squared by the pattern.

All the welded steel and iron plates to be bent at all the corners, and the corner pieces at each of the eight corners of vault to be bent into right angle triangles, the corners to be welded, making them solid; the flat plates to break joints (not to come in line) with each other on the same layer by at least 1 foot, and the welded steel and iron angles at the corners to break joints with the adjoining layer of angles by at least 4 inches.

Bolts on the two outer layers to be not more than 10 inches apart and to commence by being placed close to the joints in the plates and angles, the next layer not more than 12 inches apart, and the balance not more than 15 inches apart, all to be well counter-sunk, and those holding the inside plates of steel especially, so as to leave a smooth and flush surface inside.

DOORS AND VESTIBULES OF SAFE DEPOSIT VAULTS.

The outer door of each entrance to be as follows: First, 1-inch welded chrome steels and iron; second, 1-inch steel plate; third, one-half inch welded chrome steel and iron; fourth, one-half inch welded chrome steel and iron; fifth, one-half inch welded steel and iron tongue and grooved and welded chrome steel and iron plate; sixth, one-half inch welded chrome steel and iron; seventh, one-half inch welded chrome steel and iron; eighth, one-half inch welded chrome steel and iron; ninth, one-half inch welded chrome steel and iron; tenth, one-half inch welded steel plate, making a total thickness of 6 inches actual metal.

The outer surface 1-inch plates, forming face of doors, not to be in more than two plates in width and full height of doors; where the plates abut each other and the edges of these plates where they form edges of door, to have the first rebate planed out of the solid metal, the next layer 1-inch steel plate and bracket to have a tongue and groove planed out of the solid metal of the plate; the edges of the tongues to be serrated and grooves packed with felt or left with a smooth square edge and packed with rubber, the second tongue and groove of welded steel and iron to have the corners miterd and edges finished same as specified for outer tongue and same as specified for same as to packing.

All plates to be fastened together in the same manner as in the body of vault with the same style of bolts, no tap bolt going through more than two plates, and those holding the outer 1-inch plates and the 1-inch steel plate to be blind bolts (and not to show through either plates); bolts not to exceed 8 inches center apart throughout.

To have, in addition, to bind door together and to secure bolt frame to the door, bolts with their parallel part 1⅛ inch in diameter, made of the best wrought iron, and their conical parts of welded steel and iron, these bolts to start from the eighth plate from the outside, and are not to be more than 6-inch centers apart.

The inside doors of main entrance and inner doors of safety entrance to be as follows: First, 1-inch welded chromes teel and iron; second, one-half inch welded steel and iron tongue and welded chrome steel and iron plate; third, one-half inch welded chromo steel and iron; fourth, one-half inch welded chrome steel and iron; fifth, one-half inch welded chrome steel and iron; sixth, one half inch welded chrome steel and iron; seventh, one-half inch welded chrome steel and iron; eighth, one-half inch welded chrome steel and iron, making a total thickness of 4½ inches of actual metal.

The folding and side doors to the main entrance and the single inside door of the safety entrance to be made in the same manner as the outer doors as to the tongue and groove being miterd, serrated, and packed, etc., and also to be bolted together in the same manner, except that the parallel parts of the conical bolts are to be seven-eighths inch in diameter. These bolts are to start from the sixth plate from the outside and are not to be more than 6-inch centers apart. The outer surface of the single door is to be made of not more than two pieces in width and the full height of door; folding doors to be made of a single plate inwidth for each door.

Vestibules.—The vestibules to be constructed the same as the body except that they are to be 4½ inches in thickness, the increased thickness to be made by the addition of two layers of one-half inch welded steel and iron, the jambs surrounding the doors to be the same thickness as doors with additional thickness for bolts to shoot behind and constructed same as doors.

The angles covering the front corners to be made of welded steel and iron 6 by 6 inches by 1 inch (except at the front on the bottom where the face is to be reduced, bent and welded at all corners forming frames, and the entrance vestibule not to be made in more than four pieces, with the ends rabbeted to correspond with the door plates on the front and with the one inch welded steel and iron plates on the sides, top, and bottom, the plates between the angles to be rabbeted on all edges to correspond with the front frames at the front and with the angles of the front vestibule. The safety vestibule to be made with a solid frame welded at all corners.

The entrance vestibule to drop approximately 6 inches below the bottom of the outside of the vault, the inside floor of the vault to be kept on a line with the finished floor of the office. A working drawing to be submitted for approval as to the connection between the vestibule and the vault and also as to the construction of the drop of the same. Accurate measurements are to be taken at the building, as to the position of the beams supporting this vault and the beams in the pocket, and the work to be made to conform to same and as will be further directed by the superintendent of the works. A platform of rough rolled steel the same as the bottom of the vault to form a bridge across the vestibule entrance and a bridge of metal or wood to cover the pocket in front of the door to be in position after the door is open, or to be hinged as will be directed.

The tongue on the jambs engaging with the tongue of the steel plates to be made of welded steel and iron. The steel plate on the jamb corresponding with the steel plate of the door to be welded at all corners, making a solid frame.

If there should be a space between the vestibule and walls of vault, these are to be covered with a plate or architrave or molding, as will be directed by the superintendent of the work.

The safety entrance vestibule will probably require to be placed in position before the vault is put up, owing to the limited space between the wall of vault and the building wall. A plate, to be finished when required, one inch in thickness, to go under each vestibule.

Hinges.—The main entrance door to swing easily on a compound hinge, made of wrought iron, of sufficient strength to carry the door and not spring, and not to be less than 10 by 1¾ inches for the vertical parts, and 10 by 1½ inches for the cross-arm, with at least a 2-inch round rod on the jamb part; the cross-arms to be keyed to the round (not pinned) with anti-friction or vault bearings at the bottom, and steel pin rollers (and no other hinges to be used except the ones specified). The hinge pins on the door part to be made with a grove and spline, to prevent turning, and a screw to raise and lower same; these to be fitted up with crowned washers, and doors to rest on the top of these pins and washers.

The portions of hinges which are attached to the door and jammed together with the portions of pressure-bars attached to doors and jamb to be secured to same by means of conical bolts with welded steel and iron heads to go through the one-inch plates from the inside to hold with finished hexagon cap-nuts. The outer safety door to be made in the same manner, but to be made of lighter iron, but of suitable strength to carry the door without springing.

The inside doors to have suitable hinges with centers in center of doors to carry same into opening squarely and to allow of full tongue and groove. Each door to have a pressure bar across the door to force the back and front of doors squarely and parallel into and out of jambs at one motion. No part of the handles or connections to be made of cast iron.

Bolt-work.—The outer door of main entrance to have a continuous bolt-frame of steel welded at the corners, making solid frame, this frame to be secured to the door with the conical bolts as above specified, and to be held with a steel nut, and the nut covered with a plain bronze hexagon cover, secured with a bronze cap, the steel nuts and bolt to be keyed with a joint screw; the balance of the conical bolts in the door to be made in the same manner (but no conical rivets to be used).

Bolt frame to be 3¾ by 2¼ inches, with the necessary inside bolt frames; these bolt frames to hold at least twenty round revolving steel bolts, each to be 2 inches in diameter with anti-friction bearings in the bolt frames; bolts to be thrown with suitable handle with spindle of a pattern approved by the superintendent of the work.

The inside doors to have a continuous bolt frame, 3 by 2 inches of steel, bent and welded at all corners the same as the outer door; the conical bolts as before described securing bolt frames to the door with steel nuts countersunk in the face of the frame to save room, with joint screw keying steel nuts to the conical bolts to have a bronze hexagon casing cap to cover them, with the necessary inside bolt frames; bolt frames to hold not less than twenty round revolving steel bolts or as may be directed by the superintendent of the work, each to be 1¾ inches in diameter, with approved style of spindle to throw bolts, a sample to be submitted to the superintendent for approval.

The safety doors to have the same size of bolt frames on the outside door that the main door has and the same size on the inside doors that the inner door to the main entrance have, and to be secured in the same manner as specified for them; bolts also to be of the same size in diameter for the inner and outer doors as is called for respectively for the inner and outer doors of the main entrance.

A drawing to be submitted for approval to the superintendent giving as many bolts on each as the space on the inside of the door will admit, but to have bolts securing doors in all directions.

The inside face of all doors to have brass jiggered plates between the bolt frames, and the space between the bolt frames and the edge of doors to be ground, polished, and varnished to prevent rust.

Handles, pressure bars, and bolt and slide bars to be well coppered and then nickel plated and varnished, all bolt frames to be planed true and straight, with sharp edges, and polished and treated with a Bower-Barff process or the Rustless Iron Company's process, or as may be directed by the superintendent of the work.

The bolt work of the outer and inner main entrance doors to be covered and protected with a plate glass door, the door frame to be made of wrought iron, covered with a bronze metal finish, door secured with flat key locks, arranged that the keys of same can be removed either when locked or unlocked.

A tripping device to be arranged on each of the outer doors, so that, if necessary these doors should need to be they can be opened from the inside, a device to be operated through the spindle of the inside doors, which, in turn, is to operate upon an attachment connected with the bolt work of the outer doors, so as to release all connections between the locks and the bolt work.

Locks.—The outer doors of the main entrance to have four Sargent & Greenleaf No. 2 locks, with side shafts, locked covers and sliding bolts so arranged that it will require one lock of each set to be unlocked to release the bolt work, also a Sargent & Greenleaf or Yale triple movement, seventy-two hour, time lock, of the latest and most approved pattern.

The outer door of safety entrance to have two Sargent and Greenleaf locks same as specified for outer door of main entrance, if there is room on the door for same; if not, then a smaller lock to be used as will be directed by the superintendent of the work, to be arranged that it will require both to be opened to release the bolt work, and a time lock same as specified for outer main entrance door.

The inner doors of main entrance to have four Yale 023½ combination locks to be arranged same as specified for outer door of main entrance.

The inner door of safety entrance to have two Yale 023½ combination locks arranged same as specified for outer door of safety entrance. The bolt work to be so arranged in all cases as to be checked by a device to remove end strain from the locks and so that if locks or lock are driven from the door the locks will be held in a locked position.

The spindles of locks to be made in the most approved manner and to fit holes closely and packed with felt or rubber, a sample of same to be submitted for approval to the superintendent. Spindles to be covered with a bar same size as the outer bolt frame of the door on which the locks are placed, covering the end of spindles;

this bar to be made with welded steel and iron to be held to the door with bolts same size as the conical bolts.

Joints of doors.—Doors to be closely planed and fitted to the surrounding jams, all breaks to be filed down on their iron surface so as to come in contact with each other; great care to be taken in this matter, but contact is not expected or wanted in having doors strike sideways or up and down, which would cause doors to bind; still they must be a close fit. All breaks, tongues, and grooves to be highly polished, with steel and iron plates, to have all planer course, grounding, or other marks removed and edges polished before hardening and again to be polished after hardening.

The 1-inch solid steel plate forming frames inside the 6 by 6 by 1 inch angles on each of the vestibules to have a deep rabbet planed out of their edges on all sides, and after doors and vestibules are finished, to have strips of copper corked in them, this copper to be scraped down to a close fit.

ELECTRIC WIRES.

Sixteen insulated electric wires, made in four cables of four wires each, to be built into the vault, to go from the outside to the inside, to go through with but one plate in a direct line, then led off several inches, then the next plate, and so forth; twelve wires to be carried from the inside of the vault into the vestibules between the inner and outer doors of each, these to be tested by an electrician, at the expense of the contractor, and his certificate to be given that he has examined wires during the progress of the work and at the completion of the work, and are in good order.

DAY GATES.

The openings of vault each to have a swinging day gate of special design, with guard plates to protect the lock, with suitable bronze spring lock; these gates to swing on gravity hinges to make them self-closing.

WOOD BRIDGE.

To furnish a bridge to be made of oak or mahogany to bridge over the entrance to vault, to be stiffened on the under side with bridge-stiffening pieces, the under side to be well painted, the upper side to be filled in with wood filler and rubbed down and varnished, the edges to be shod with brass. (For further particulars in relation to this see Vestibule.)

GRILLE GATES AND VESTIBULE.

The gates of storage vault to be made of an outer and inner pair of grille gates formed of 3 by 1 inch bar iron with 1¼-inch round bars, placed about 3¼ inches centers apart, to be doweled into the flats at the top and bottom; gates to swing on heavy wrought-iron hinges, well bolted or riveted to both gates and jamb at the rear.

Both right and left hand gates to be bolted and held with 1-inch round bolts, these bolts to operate in the first bar nearest the front edges of gates, this bar to be made of rolled tubing, these bolts to be made the full length of the tubing. The wheel operating these bolts and lock to be protected on each side of each door with one-half inch welded steel and iron plates on the outside and iron plates on the inside, secured to the rounds and flat bars. Bolts to be thrown with suitable nickel-plated drop handle and secured with a Sargent & Greenleaf bronze key lock.

The vestibule to be lined with one-quarter inch plate iron with 2½ by 2½ by ⅜-inch wrought angle iron corners between the hanging frames of gates.

The outer and inner sets of gates to have suitable hanging frames of 4 by 4 by ½-inch angle iron to be welded at the top corners and doweled into a wrought-iron saddle at the bottom at both front and back; these saddles to be chamfered on both edges, the angle frames with their saddles to be secured to the one-quarter inch lining plates with three-eighth inch countersunk head rivets on the front and with three-eighth inch countersunk head screws with square heads in the rear, the heads to be cut off, leaving screws flush, the gates when closed covering the screws, the panels formed by the frames and angles to be finished with a neat corner molding, gates to be stopped at the top, but no stop at the bottom, the bolts to be well fitted securing gates, one gate of each set to have a button covering open in the center where the pair of gates meet; the face of front frame to be covered with a molding or to correspond with the frame of the safe-deposit vault doors

DOORS FOR THE STORAGE VAULT.

The doors for the storage vault in the cellar under the safe-deposit vault will be made for the main entrance with the door to swing into the vault and the safety opening with the door to swing out; working plans of both these sets of doors to be submitted to the superintendent of the work for acceptance.

It will depend upon the condition of the building as to getting in the safety vestibule, owing to the limited room between the vault and the inside face of wall of the building; the construction of vestibule will depend upon this, but will be determined upon by the architect, superintendent of the work, and the contractor.

Doors.—Both doors to be made as follows: First, one-half inch steel plate; second, one-half inch welded chrome steel and iron; third, one-half inch welded chrome steel and iron; fourth, one-half inch welded chrome steel and iron; fifth one-half inch steel plate, making a total thickness of 2½ inches of actual metal.

The plates to be well secured together with three-quarters inch bolts, same as in safe-deposit vault, and not to exceed 8-inch centers apart throughout. and no bolt to go through more than two plates, and no two bolts to be opposite each other, and to have in addition to bind door together and to secure bolt frame to the door, bolts with their parallel parts seven-eighths of an inch in diameter, made of the best wrought iron, and their conical parts of welded steel and iron, these bolts to start from the fourth layer from the outside and are not to be more than 8 inches centers apart, each layer of metal to form a rebate or break.

Vestibules.—The vestibules to be made of, first, one-half inch steel plate; second, one-half inch welded chrome steel and iron; third, one-half inch steel plate, making a total thickness of 1½ inches of actual metal.

The frames to be made of 4 by 4 by ½-inch wrought angle iron bent and welded at all corners, forming solid frame, the welded steel and iron to be bent into knees and to be secured to these frames on the front and also bent into knees to form a part of the jambs of doors, the welded steel and iron to be well secured to the inside plates in the vestibule opening and the outer plate to the welded steel and iron, no screw to go through more than two plates; the corners from front to rear to be covered on the outside and inside with 4 by 4 by ½-inch angle iron, secured as before specified, no bolts to go through more than two plates, etc., these bolts all to be three-quarter inch, countersunk, of welded steel and iron.

The inside frames to clamp the vestibules in place to lap on the wall at least 4 inches and to be secured with three-quarter inch bolts, placed not less than 8 inches centers apart. Bars at least 3½ by 2 inches to be bolted to the frame of the main entrance door at the top and sides, these bars to be well bolted to the inside of frame with three-quarter inch bolts for bolts to shoot into, and the bottom bolts to shoot into a plate at the bottom.

The inside plates of jamb of vestibule to be well secured to take strain, as the strength of the work depends upon the proper bolting.

Hinges.—The hinges to be made of either wrought or malleable cast iron of sufficient strength to carry doors; the pins to be of steel and the top part of the hinge to rest on the top of the hinge pin.

Bolt work.—The doors to have on each a continuous bolt frame of steel, 2¾ by 1½ inches, to be bent and welded at all corners and held to door with the conical bolts before specified, and secured by nuts of same, keyed with joint screws; the nuts to be covered with bronze covers and held with a bronze cap secured to the end of the conical bolts. The necessary inside bolt frame to make the work secure.

The main entrance door to have at least twenty round revolving bolts, and the safety door at least ten round revolving bolts; bolts to be 1⅝ inches in diameter, of steel. These bolts to be thrown from the outside, with suitable handles, the spindles to be well fitted and packed, and to be of a pattern approved by the superintendent of the work; style of same to be submitted by the contractor for approval. The inside face of doors to be painted as will be directed. Handles, pressure bars, all bolt and slide bars, to be copper-plated, nickel-plated, and then well varnished, to prevent rust; all bolt bars to be planed true and straight, with sharp edges and corners, and polished and treated with the "Bower-Barff," or the Rustless Iron Company process, and as will be directed by the superintendent of the work.

Joints of doors.—The doors to be closely planed and fitted to the surrounding jambs, and to be closely planed and fitted and finished in aluminium bronze, same as doors.

Locks.—Each door to have two Sargent & Greenleaf No. 2 automatic outside shaft combination locks with locked covers and sliding bolts to be so arranged that it will require both to be opened to release bolt work, and in all respects to be put on same as specified for vault doors of safe-deposit vault, and also secured with a Sargent & Greenleaf or Yale seventy-two hour three-movement time lock of the most approved pattern on each door.

The spindles of locks to be made to fit holes closely and to be packed with felt or rubber, style of spindles to be submitted to the superintendent of the work for approval, to have a bar covering the ends of spindles to be the same size as the bolt frames and secured to the doors by bolts the same size as the conical bolts, this bar to be made of welded steel and iron.

DAY GATES.

The gate to the main entrance to be self-closing sliding gate and the one for the safety door is to be a swinging day gate, both to be of special design with good and sufficient guard plates to protect the lock, with suitable bronze spring locks, both to be self-closing gravity gates.

PAINTING.

All work to be free of rust and oil, the inside of vault to have in addition to the usual priming coats at least three coats of white lead and linseed oil, and heads of screws and joints to be well filled and puttied, making a smooth finish, and to be well covered.

The entire outside surface of all doors and jambs with the inside of vestibules to have the usual priming coats and to be made smooth with filler and rubbed down to a smooth surface and finished in aluminum bronze and with such other ornamenting as will be directed on application to the superintendent of the work.

The Grille gates to be well painted and finished in aluminum bronze.

PROPOSED SPECIFICATION FOR BURGLAR-PROOF TREASURY VAULTS, SUCH AS ARE RECOMMENDED BY AN EXPERT IN THIS BUSINESS.

For a vault 3¼ inches in thickness the outer plate should be 1½ inches thick, composed of three layers of material, welded solidly together in plate rolls. The outer layer should be one-eighth of an inch of soft steel, the second layer should be three-eighths of an inch of chrome steel, and the third layer should be 1 inch of soft steel. These plates should be at least 4 feet in width, running the full height of the vault, and on the top and bottom not less than 10 feet in length.

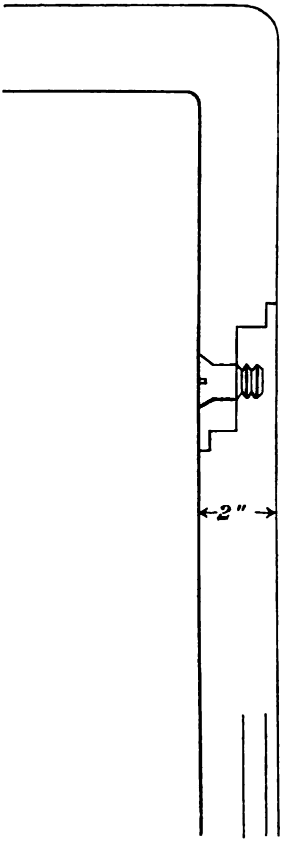
The angle irons at the corners should be 12 inches each way, composed of the same material. That is, 1½-inch plates should be rabbeted to the 1½-inch angle iron, with three rabbets not over one-fourth of an inch in width for each; 12 by 12-inch angles should be welded at the corners, making a tripod which should not be jointed at the center of the height of the vault, but should run the entire height, making one long leg with two short ones on each end. These short legs should not be less than 3 feet in length.

Secured to this outer plate and to these angles should be a layer of three-quarter-inch five-ply welded chrome steel and iron plates, and bolted to the 1½-inch outer plates with welded steel chrome and iron bolts, 1¼-inch diameter, going 1 inch into the outside plate, with threads not less than twelve to the inch. These bolts should be placed 12-inch centers each way, and at every joint should be not more than 3 inches away from the joint on both sides, and 12 inches centers in the other direction. Secured to this three-quarter-inch plate should be a second plate of same material, secured in the same manner, with bolts 1-inch diameter, threads not less than sixteen to the inch, placed 12 inches centers, not coming opposite bolts in the second plate. These welded chrome steel and iron plates to be not less than 4 feet wide and 10 feet long. Inside of these plates forming the interior lining of the vault, should be plates one-quarter-inch soft steel or Bessemer not less than 5 feet in width and 12 feet in length, where the vault will permit it. A 12-inch angle running all around the corners of the vault, made in the same way as specified for the outer angles. This makes the vault 3 by 3¼ inches in thickness, for which the outer door should be 6 inches thick, having three tongues and grooves all around the edges, and construct the same as the shell of the vault, excepting that the additional thickness shall be made up of three-quarter-inch, five-ply, welded chrome steel and iron. The inner doors shall be 4 inches in thickness, in one fold, with two tongues and grooves around edges. Both outer and inner door to be hung upon crane hinges, both doors to have lock frames of steel, at least 4 by 2 inches welded at all corners with twenty-four steel revolving bolts 2½ inches diameter.

All nickel and bronze plated, as required, all moving easily with one handle, which shall be so constructed as to prevent any clear hole more than one-third the thickness of either door, and what is known as the "offset handle." Each door secured with chronometer locks, best make, and each door to have two dial clocks of best make. Inside of both doors to be covered with bronzed plates, one-eighth of an inch in thickness. Every plate in the vault and doors to be tested by heavy drilling machines wherever indicated by inspector.

After material is tempered all joints shall be close—no open joints to be accepted.

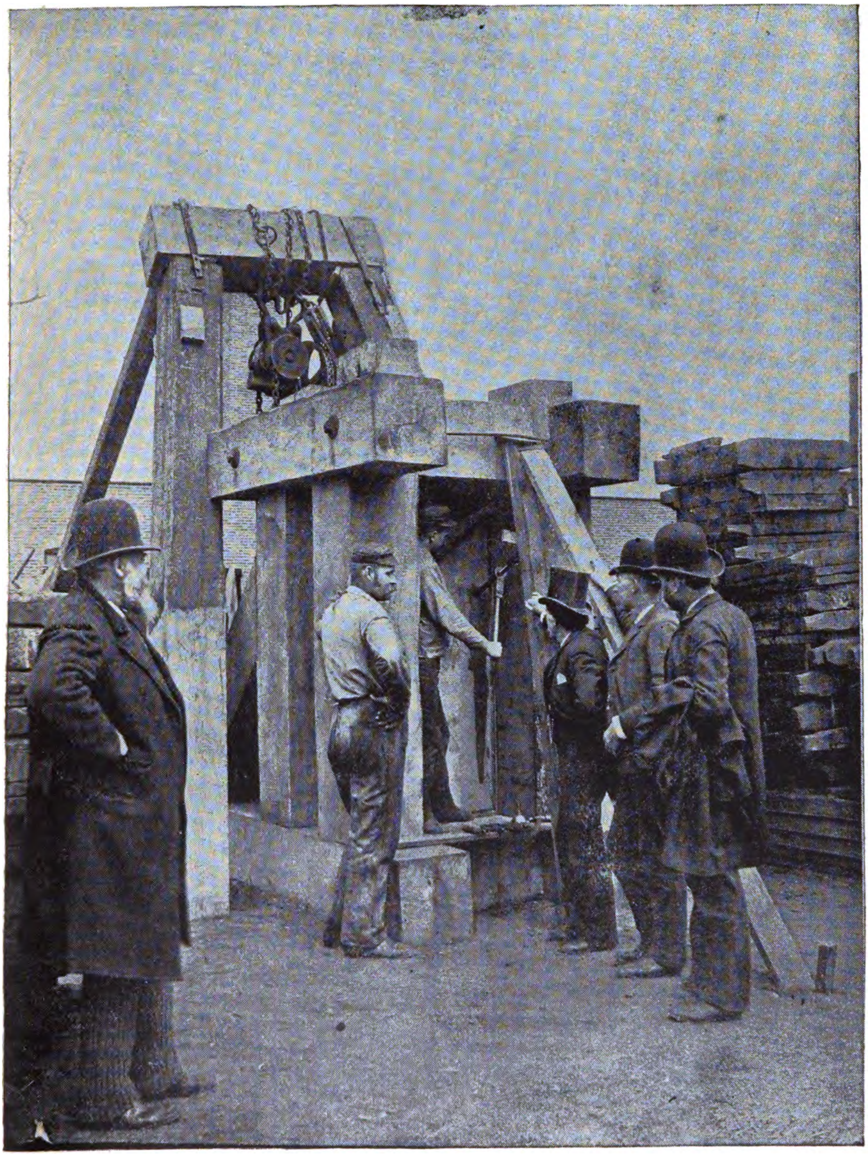
The vestibule should be 5 inches thick, made in same manner as the outer door. The frame for vestibule should be made in the same manner as the frames for vault. Tongues and grooves in doors shall fit within one-sixty-fourth of an inch in all places. Adjustable set screws shall be placed for each crane hinge, to take up any wear in the working of the door.

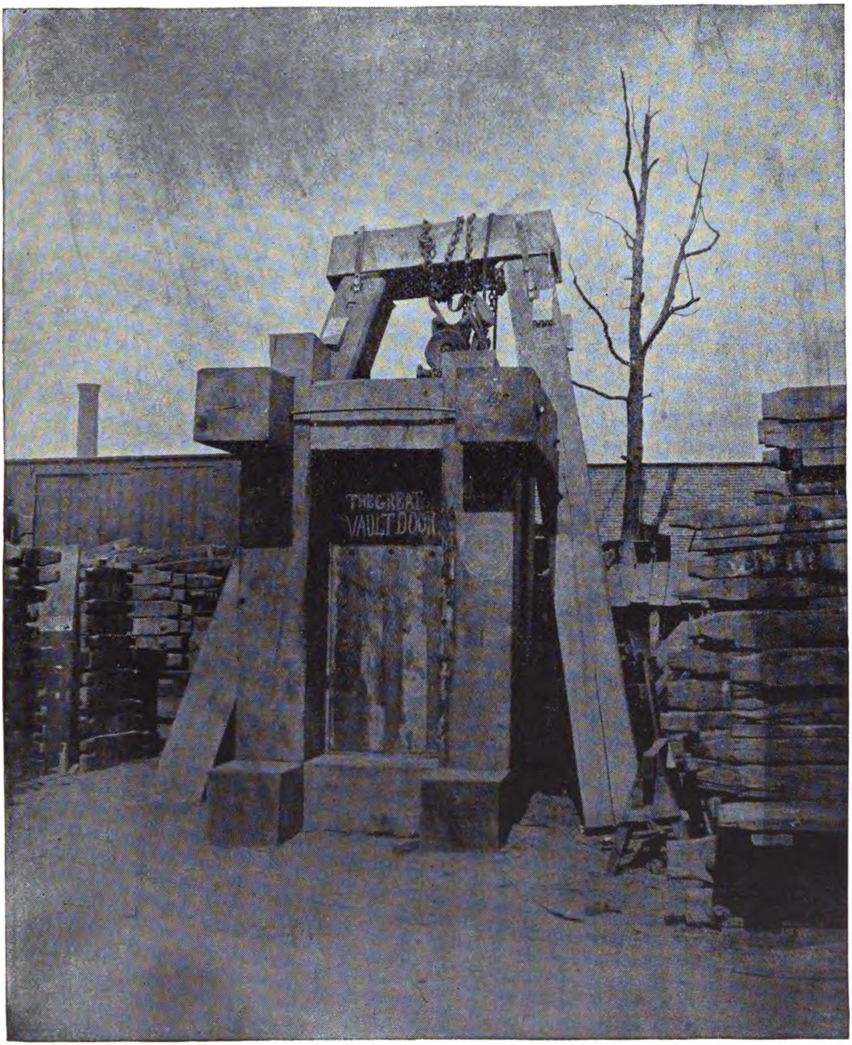


All material painted two coats of Prince's metallic paint before being put together.

In making a vault four inches thick, would adopt the same plan, excepting that the outer plate should be 2 inches instead of 1½ inches, and angle irons be 2 inches also. Where 2-inch angle irons are used there should be a rabbet of at least 3 inches in width in both plate and angles. Inch blind bolts should be placed not more than 10-inch centers. The same plan should be adopted for the joints of 2-inch plates. This in addition to the one-fourth-inch rabbets previously specified. The inside lining to be one-half inch thick of Bessemer steel.

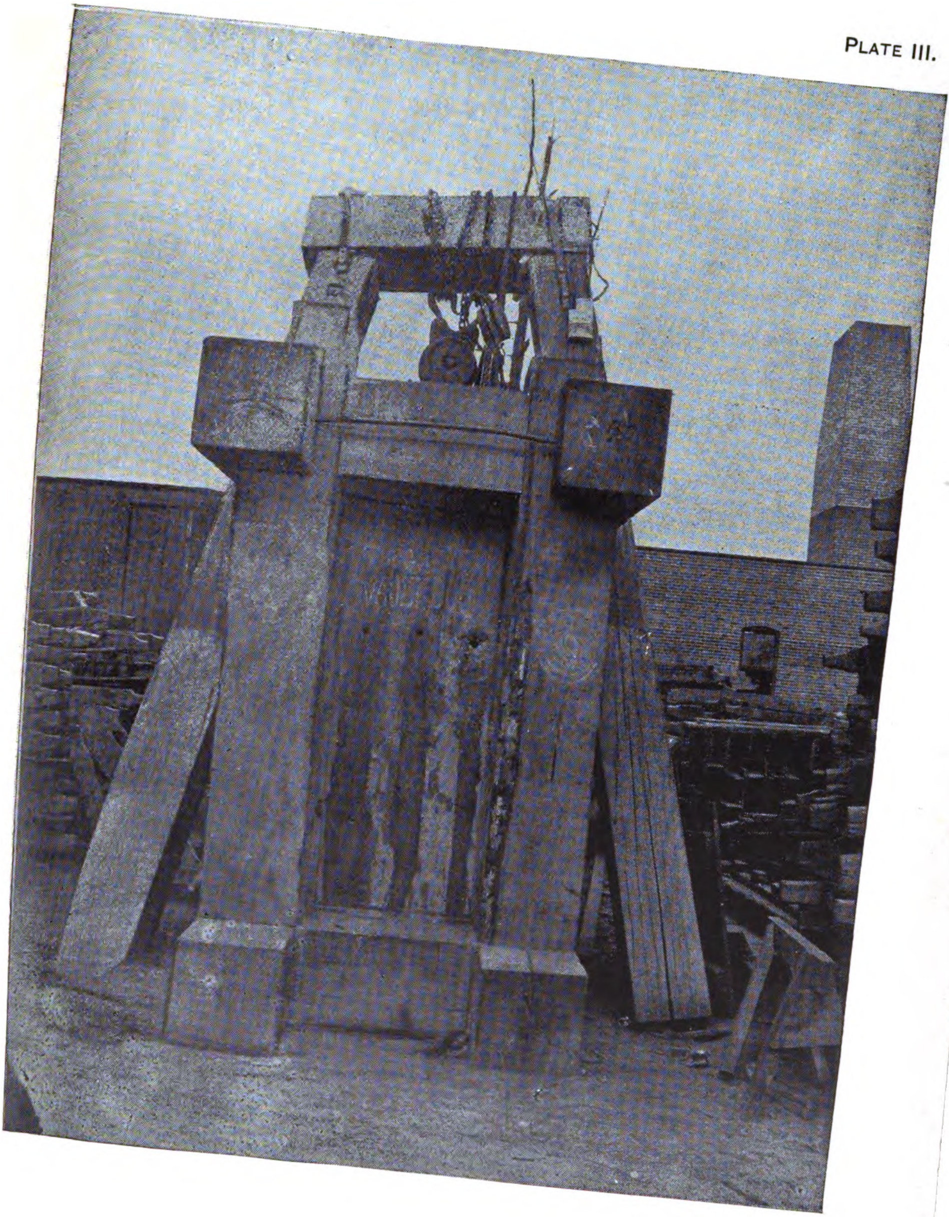
○




THE GREAT
VAULT DOOR

Appendix A.

PLATE III.



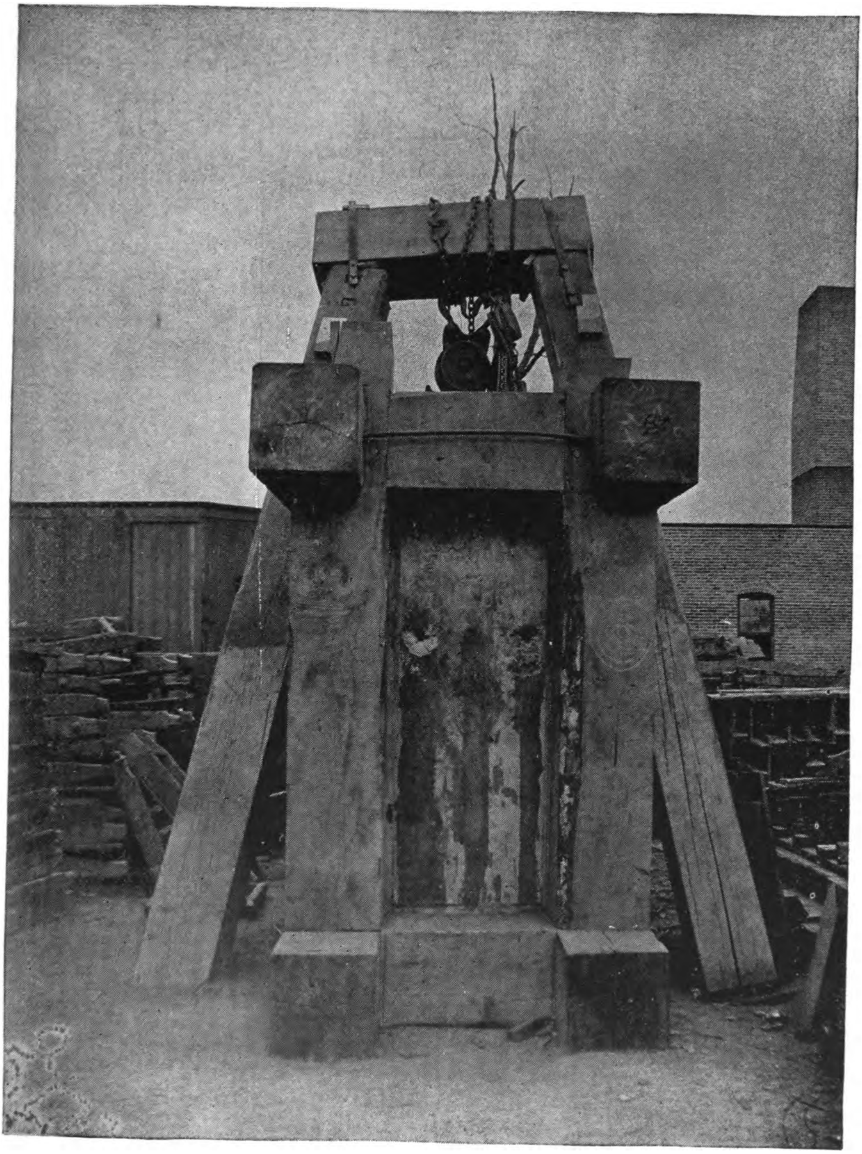
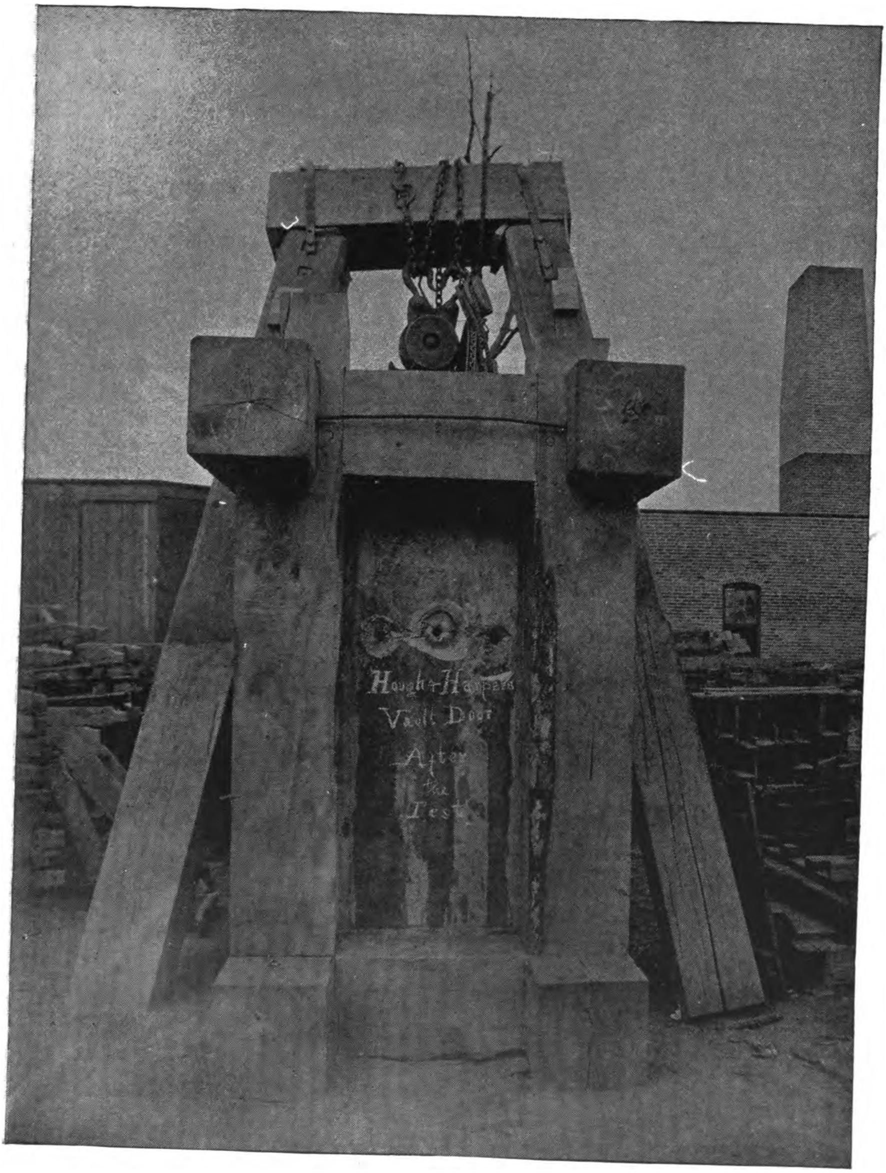


PLATE V.



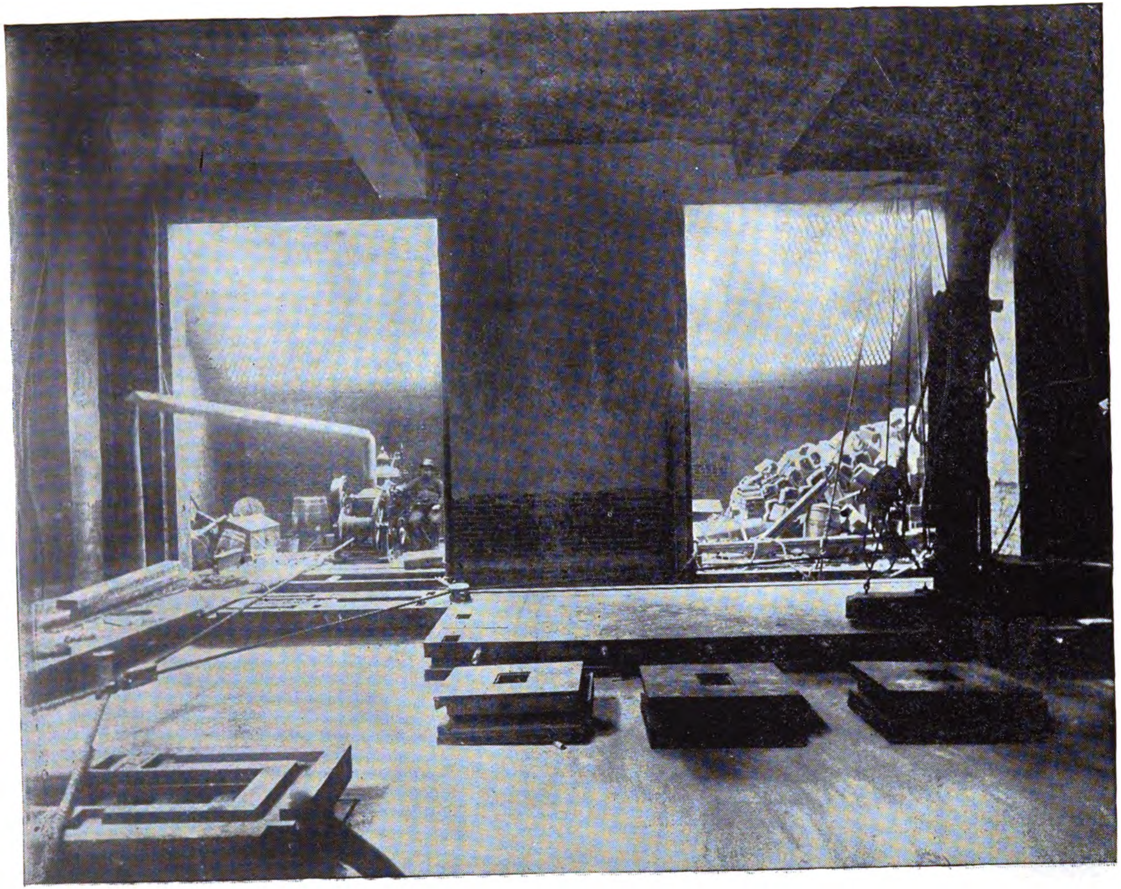
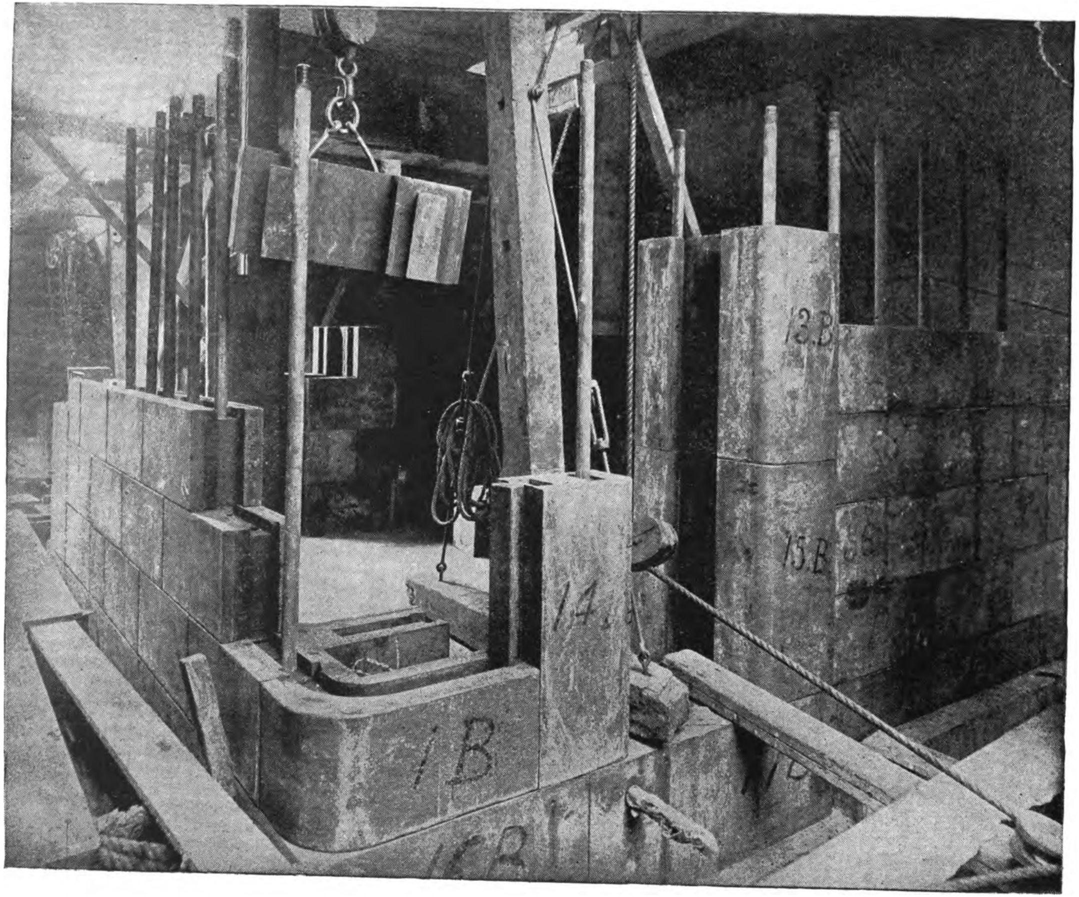


PLATE VII.



3 2044 010 017 234

The borrower must return this item on or before
the last date stamped below. If anot
places a recall for this item, the borro
be notified of the need for an earlier ret

Non-receipt of overdue notices does ***not***
the borrower from overdue fines.

Harvard College Widener Librar
Cambridge, MA 02138 617-495-2

WIDENER
MAY 06 2004
CANCELLED

WIDENER
MAY 16 2004
BOOK DUE

Please handle with care.
Thank you for helping to preserve
library collections at Harvard.

PLATE VI.

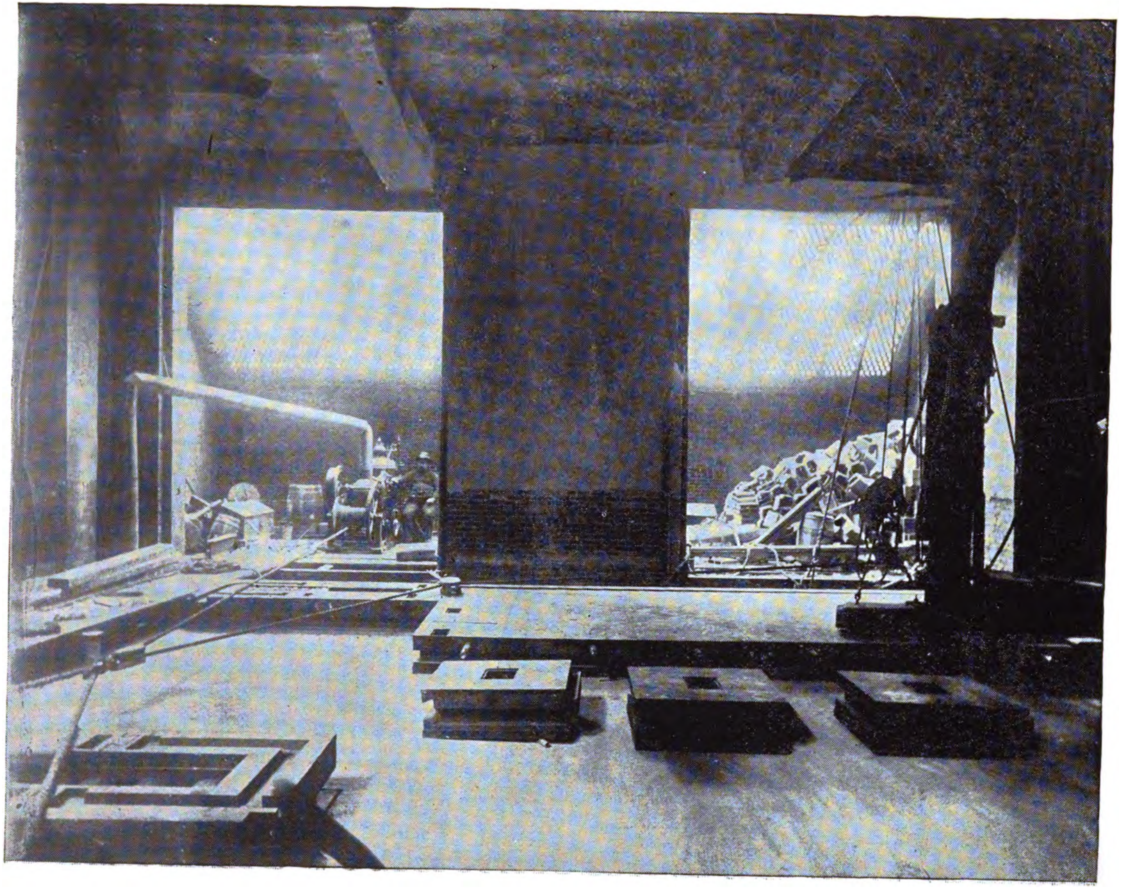
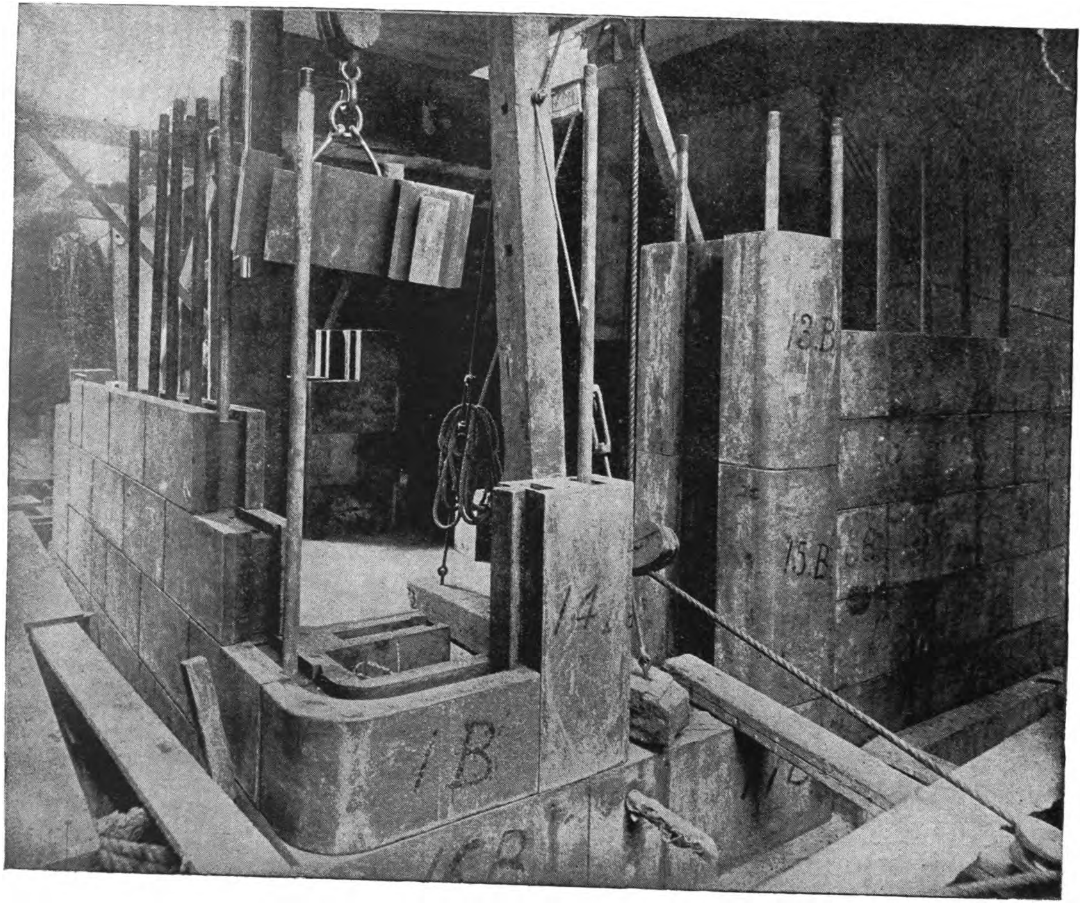


PLATE VII.



3 2044 010 017 234

The borrower must return this item on or before
the last date stamped below. If anot
places a recall for this item, the borro
be notified of the need for an earlier re

Non-receipt of overdue notices does ***not***
the borrower from overdue fines.

Harvard College Widener Librar
Cambridge, MA 02138 617-495-2

WIDENER
MAY 06 2004
CANCELLED

WIDENER
MAY 16 2004
BOOK DUE

Please handle with care.
Thank you for helping to preserve
library collections at Harvard.